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LINEAR RESPONSE POLICY FOR SEQUENTIAL SOURCING WITH CORRELATED YIELDS

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ABSTRACT

This thesis analyzes the problem of dual period sequential seed corn production in the presence of random yields. Seed corn producers in the United States face a production problem when growing seed corn to meet the national demand. If the growing season is poor due to drought, disease, or natural disaster, seed corn supply decreases, and there is not sufficient seed corn available to meet the demand. As a result, large seed corn companies such as Dow AgroSciences, DuPont, and Syngenta have shifted to a two-hemisphere production model. This allows a seed corn producer to compensate for a poor first period production in the United States by planting additional land in the South America during the second production period. The challenge the firm faces is that the second period production is dependent on the first period production, and the first period production is dependent on the second period production. The model used in this paper chose an optimal land area to plant in the first period factoring in a second production period. Monte Carlo simulations were used to solve the firm’s problem. The results indicated that firms can increase their expected profit by up to 7% by producing the seed two times instead of only one time.

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Chapter 1

Sequential Production, Problem and Introduction

1.1 Problem Context

In the United States agricultural industry, demand for seed corn comes annually between the months of April - June. Farmers purchase quantities of several hundred varieties of seed corn available from several producers to plant in their fields. The amount of seed corn required varies from year to year based on market demand and growers' preference. Even if the demand is known, growing seed corn is inherently risky, due to unknown factors such as weather and pests which effect total yield. In order to meet a given level of demand, seed corn producers must build resilience into their systems. Recently, producers have sought to reduce risk by growing seed corn in two production periods, the first production period in the United States (April-September), and the second-production in South America (January-April).

The second production allows firms to respond to poor yields in the first production and increases the probability that seed corn demand will be met. One of the challenges with this method is ensuring that the correct amount of acreage is planted to maximize the expected profit and ensuring that the supply of seed corn is enough to meet the market demand. Typically, the second-period production is more costly than first-period production. Therefore, it is desirable for the firm to produce the bulk of the seed in the United States. At the same time, it is important for the firm to maintain the capacity in South America to plant further acreage if yields are poor following the seed corn production period in the United States.

This paper addresses two closely related questions in this context, (1) what is the value of dual-production over single production in which seeds are produced only in the United States, and (ii) develop a managerially friendly but rigorous methodology to solve the single and dual-production problems. This paper differs from previous work on this problem in that it uses simulation software rather than stochastic programming. Our objective was to solve the production area problem in a spreadsheet environment. Using simulation software in a spreadsheet environment gives operations managers at seed firms the opportunity to use the software that they are familiar with and understand. The simulation software used is @Risk version 6, by sold by Palisade Inc.

This paper utilized data provided by our research partner, Dow AgroSciences http://www.dowagro.com/ . Dow AgroSciences is one of several large agribusinesses that are producing seed corn using the dual period production technique in both the United States and South America. The estimate for the value of dual-production is based on the data obtained from Dow AgroSciences, though we believe that it is representative of this industry.

1.2 Literature Review

Given the business decision making focus of the research problem, the literature review of this paper is restricted to operations management literature on seed corn business. As a result, papers pertinent to single period and dual period seed corn production are discussed. No papers published after 2005 were found addressing dual period sequential corn production. One reason for a lack of papers in the public domain is that much of the research in this area is proprietary and funded in part by seed corn production firms. The reader is referred to Chapter 2 for details on the technical details of seed corn production.

The seed corn business provides the seeds needed to grow the grain that maintains livestock production and human consumption. However, the operations management literature in this area at the present time is sparse. Lowe and Preckel (2005) provide a review of the literature completed in agribusiness decision-making. This paper reviews decision-making in the agricultural sector using linear programming, stochastic programming, risk programming, dynamic programming, and simulation. Dillon et al. (1989) created a simulation model designed to produce data to be used as inputs in a land area-allocation model based on quadratic programming. Saseendran et al. (1998) also created a biophysical simulation model to assist in determining the transplanting dates for rice seedlings.

In the seed corn industry, there are two primary types of uncertainty, seed demand and supply according to Lowe et al (2002). The demand is uncertain because farmers frequently change the crop rotation that they use, and require different seeds. We focus is on this environment with random demand. The number of seeds offered in the market is large, with many firms offering more than 100 hybrid seed-corn varieties according to Lowe et al (2002). Lowe and Preckel (2005) note the complexity of inventory management of various seeds due to their substitutability and identify inventory management of substitutable seeds as an important area of research. The supply is uncertain because the amount of seed obtained from each acre of land is based on a large number of variable factors. Seed firms typically produce seed corn in-house to assure quality, and assume the risks and profits associated with high profit-margin seeds like corn seeds. Jones et al (2001), and Jones et al (2003) investigate this problem of selecting optimal land area to grow seed corn. On the other hand, soybean seeds are low-margin seeds. In our communications with seed firms, we have found that seed firms typically purchase these seeds from a third-party and then treat them with proprietary pesticide and herbicide treatment and sell them.

An important and well-studied area for seed production pertains to the distribution family of yields. Atwood (2003) and Jones et al (2001) have assumed a normal distribution of seed corn yields when modeling production scenarios. But others such as Hennessy (2009) have argued that normally distributed yields do not adequately represent reality. It appears to us that there is no definitive answer for this issue. In the past 20 years, significant research has been done on the yield distribution of corn and other staple crops in North America, Hennessy (2009). Most of the research completed on seed corn production yield distributions analyzes crop failure insurance premiums for farmers and landowners. The research completed for crop failure insurance can be applied directly to seed corn yields, because it takes into account the same components present in conventional corn production operations. While seed corn requires a higher level of care to ensure an acceptable end product, it is grown in largely the same way as conventional corn used for feed. The methodology developed in this paper is general and can be used for any family of yield distributions. The Monte Carlo simulation model used in this research works for any yield distribution. For illustration purposes, it was assumed that the yields in this research follow a normal distribution.

1.4 Thesis Content Overview

In chapter 2, an overview of seed corn production with an explanation of the history of the industry, land requirements, equipment, and a production process diagram is provided. Chapter 3 covers the model used for analyzing the problem and data. Chapter 4 discusses the research completed and the solution determined. Chapter 5 addresses the benefits of dual-production and summarizes the methodology and findings of the paper.

Chapter 2

Seed corn Production and Detasseling Systems

Seed corn production in both the United States and South America is a complex, precisely-managed system that has developed since the advent of mass-produced hybrid corn in the 1940s. Figure 2.1 details the factors involved in seed corn production and sale, and provides an overview of the factors influencing the long-term profit of Dow AgroSciences.

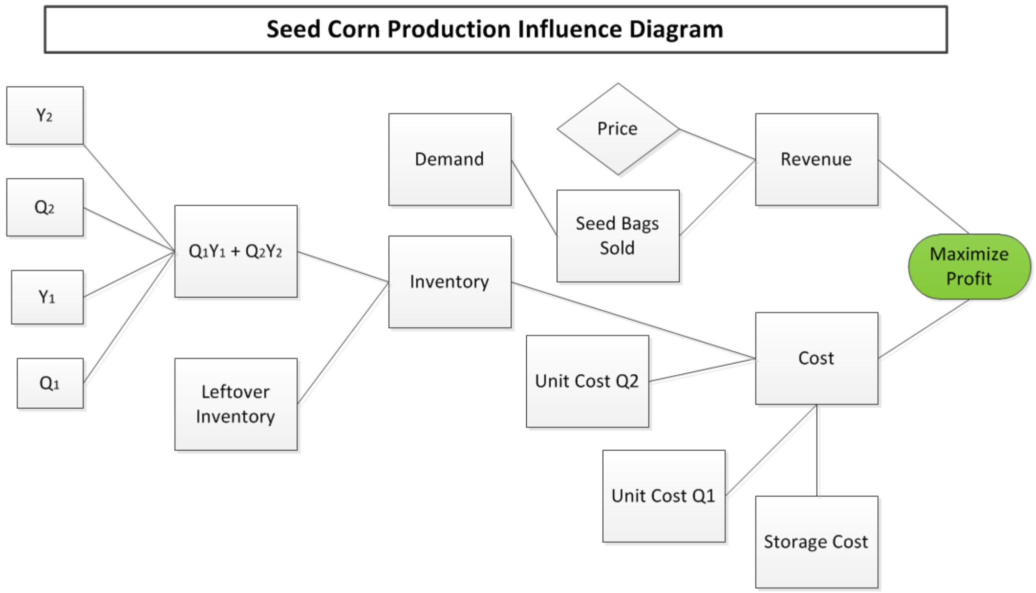


Figure 2.1 Seed Corn Production Influence Diagram

In Figure 2.1, production starts in the left column. Q_1 signifies the land area planted in the first production period. Y_1 indicates the yield per land-area planted. Q_2 indicates the land planted in the second production period, Y_2indicates the yield per land area planted. $Q_1Y_1 + Q_2Y_2$ signifies the supply produced during the current production year. This combined with inventory remaining from the previous year is equal to the total seed corn inventory that Dow AgroSciences has available for sale. Dow AgroSciences' primary cost is incurred in the form of tillage and crop growing cost per acre of land. Therefore this cost is equal to the acreage used to grow seed times the per acre tillage cost. We assume that the demand is fixed, and can be predicted based on previous sales and market trends. The number of units (bags) of seed sold will be the same as the demand unless supply is less than demand. In this case units sold will be equal to inventory. Revenue is equal to units sold times the unit price, and profit will be equal to the total cost subtracted from the total revenue. The goal of this study is to assist Dow AgroSciences in maximizing the profit gained from the seed corn operation by determining the optimum values of Q_1 and Q_2.

In order to better understand the optimal solution for this problem, a basic understanding of seed corn production and context is valuable. The remainder of this chapter provides a summary of several key components in seed corn production.

2.1 Land Selection

The time-dependent nature of seed corn production makes land selection a vital component of the production process. It is crucial that all the female corn plants develop at the same rate in order to ensure uniform emergence and generation throughout the entire field. In order to guarantee this, soil moisture, temperature, and soil-to-seed contact, must be kept relatively constant. Other issues such as wet spots, crust formation, and soil compaction affect maturation rates according Thomison (2010). Not only do these problems reduce the quality and quantity of the seed leaving the field, they also present problems in the hybrid crossing process. In order for detasseling machines to be effective, the corn plant height must be similar. For female corn plants to be pollinated, it’s crucial that their silks must emerge just as the tassels on the male plants begin to release pollen. The silks on the female plants can then receive pollen from the male plant as it is naturally blown throughout the field. If the detasseling machine and team of manual detasselers fail to effectively remove the tassel from the female corn, it may self-fertilize, eliminating the chance of the seed corn becoming viable hybrid seed. As a result, the fields used for production of seed corn must be carefully examined for uniformity, to ensure correct emergence and germination throughout the entire field.

2.2 Planting

While there are several ways that field corn can be planted, the primary method used in the United States is an equally interspaced row system. This typically involves evenly spacing female seed corn rows throughout the field with a modified corn planter, and following this planter with a second planter containing male seed corn. These male rows are spaced evenly between every three rows of female corn according to Roth and Breining (2014). After the corn matures and the tassels are removed from the female plants, the female silks will receive pollen from the male tassels, Thomison (2013).

2.3 Maintenance

Due to the value and requirements in place for the seed corn crop, precise herbicide and fertilizer application is necessary. While the process is very similar to a conventional corn system, more attention is paid to the corn while it is being grown. In addition to the herbicides and pesticides used in conventional corn production, fungicides are used heavily to prevent fungus from developing on the plant leaves that have been cut by the chopping and detasseling machines used for removing tassels from the female plants. The removal of plant material leaves the plants more susceptible to funguses and requires the application of additional fungicides.

2.4 Corn Chopping/Detasseling

In order to produce hybrid seed corn, field managers must ensure that the female corn plants are completely detasseled. Detasseling must be done once to allow the male corn plants to pollinate female corn plants. Removing the tassels prevents the female corn plant from self-pollinating and leaves the female silk open to receive pollen from the male corn tassel. Seed corn fields are typically planted in a 3 female to 1 male row-pattern. Because the female seed corn is the corn that becomes the hybrid seed, commercial producers design the field to use as few male rows as possible, while still maintaining full coverage and ensure that all the female seeds to be fertilized by the pollen from the male plants.

Prior to detasseling, a clipper or chopping machine is sent through the fields, to level the plants – removing any leaves standing out, as well as 30-50% of the tassel. A Hagie 204SP chopper can be seen below in figures 2.2 and 2.3. The chopper has a 4 cylinder 4.5L 160 HP Cummins QSB Turbocharged engine, with a full-time four wheel hydraulic drivetrain system, and a dry weight of 10,200 lbs according to Hagie Manufacturing Company (2014).

Figure 2.2 Hagie 204SP Corn Chopper

http://talk.newagtalk.com/forums/thread-view.asp?tid=108965&DisplayType=flat&setCookie=1

The assembly used on each chopper head is a hydraulically-driven 19 inch blade that rotates at 3100RPM. There is a hydraulically driven blade for each row of female corn. The feeding forks seen in figure 2.3 are used to feed the corn leaves and tassels into the cutter assembly.

Figure 2.3 Hagie 204SP Corn Chopper Cutter Assembly

http://talk.newagtalk.com/forums/thread-view.asp?tid=108965&DisplayType=flat&setCookie=1

The 2014 Hagie 204SP chopper includes photo light sensors on each head to detect distance from the plant and determine the correct cutting height. According to the Hagie chopper/detasseler manual (2013), these can be manually overridden by the operator if the operator prefers to chop at a height that differs from the photo light sensor settings. Both sensor light sensitivity and machine arm response time can be adjusted to fit operator preferences. The sensors use high intensity 9000 series LED photocells and allow the machine to be run in dark and rainy conditions, according to Hagie 204SP Specification Materials (2014).

Following the clipping, the field is generally left for 1-2 days before detasseling according to Breining (2014). Traditionally, corn tassels have been removed by hand. Hybrid seed corn began to be produced on a large-scale in the 1950's. However, the introduction of mechanical detasseling equipment significantly reduced the hardship and drudgery associated with manually pulling tassels off of the female corn husks according to Roth (2014). Often the same machine is used for both the chopping and detasseling operations. However, a different attachment is use to removed the corn tassels. Figures 2.4 and 2.5 display a typical detasseling head.

Figure 2.4 Oxbo TS2 Detasseler Head

http://oxbocorp.com/Products/Seed/TS2Detasseler.aspx

The hydraulically driven pneumatic tires on the attachment arms in figures 2.4 and 2.5 grasp the tassels that are fed in by the wire forks and remove the tassels by pinching them as the machine moves past. These generally use the same type of sensors as those used by the chopping implement.

Figure 2.5 Hagie 204SP Detasseler Head

http://2.bp.blogspot.com/_w_qrFQa9Ai4/Se-cUOOoerI/AAAAAAAAAAM/7VptQyjTPWc/S220/hagie.jpg

Depending on weather and environmental conditions, the mechanical detasseling process is 40-90% effective. Detasseling machines function better in dryer conditions. Due to the tight constraints on hybrid seeds requiring the seed to meet rigorous purity standards, laborers are hired to follow the detasseling machine and remove any remaining tassels that the machine failed to remove. By employing a team of workers, the manager or producer can ensure that the majority of tassels are removed. In the US, detasselers have traditionally been young adults aged 14-18, who are able to work for the duration of the detasseling season which begins at approximately in late June or early July each year and lasts 2-3 weeks, ending in late July according to DuPont (2012).

There are several system constraints that a field manager faces when detasseling seed corn. Wet weather reduces the efficacy of corn choppers and detasselers, and requires ground teams to spend increased time in the field pulling tassels that the machines missed. The detasseling must be completed within a one to two week period, and if the weather in not ideal, the corn must still be detasseled. Each female corn plant that is not detasseled will self-fertilize, and the seed produced will not be the required hybrid seed. Weather, machinery, availability of workers, and time constraints all play a critical role in maintaining expected seed corn yield.

2.5 Harvest

Following the mechanical detasseling, the seed corn is left, and the male tassels release their pollen. This reaches the female rows and allows them to be pollinated. Once the fertilization is complete, machines are sent through the fields to remove the male cornstalks. This may be done using a chopping machine, or by running the male rows into the ground with tractor tires. This reduces competition for light, nutrients, and water, and gives the female plants a better chance to mature. The corn continues to grow until it is ready for harvest. At this point, the corn is harvested on the cob using either a sweet corn harvester or a seed corn harvester. The Oxbo 2485 Harvester is a typical piece of equipment that can be used to harvest both sweet corn and seed corn. It harvests the corn cobs with the husks on them, and then uses a conveyer belt to place the whole cobs in a bin located behind the cab. When the bin fills to its 16,000 lb capacity, it can be dumped into a vehicle for transport to the processing facility. The 2014 Oxbo 2485 weighs 33,060 lbs without a seed corn header, and is powered by a 9.0L John Deere engine. It can harvest 8 rows of seed corn per pass. The harvester uses on a four wheel drive mechanical drivetrain for transport and can harvest up to 30 tons of seed corn per hour. The unit has a 240 gallon fuel tank which allows it to run at full capacity for 24 hours before refueling. This is important in order to be able to harvest seed corn when weather conditions are appropriate.

Figure 2.6 Oxbo 2485 Seed Corn Harvester

http://www.oxbocorp.com/Products/Seed/2485.aspx

Following harvest, the corn cobs are then taken and processed at a seed corn processing plant, sorted to eliminate non-viable cobs, and then dried.

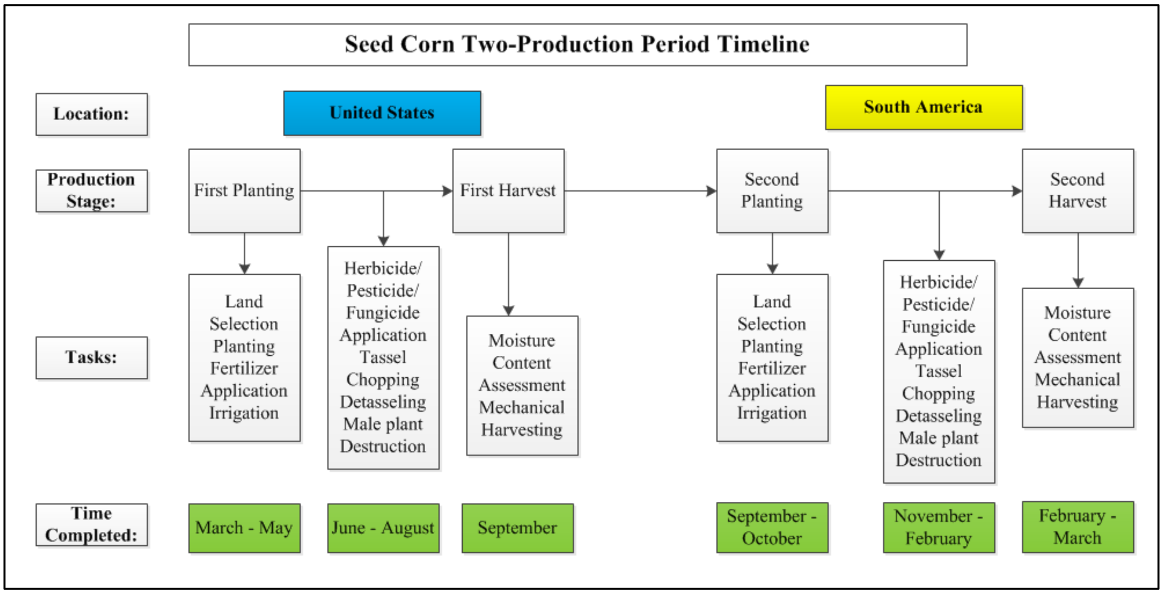


Figure 2.7 Seed Corn Two-Production Period Timeline.

Figure 2.7 provides an overview of the processes involves in producing seed corn. These are standard across the commercial seed corn production. The second production period repeats the same tasks as the first period; it only differs in its location and the time period in which it takes place.

Chapter 3

Seed Corn Production Optimization Model

Based on the system explanation outlined in the corn seed production section, it becomes apparent that the firm has a three period problem to solve. In the first period the acreage to be planted in the United States is determined. In the second period, the yield from the area planted in period 1 is determined. In the second period, the acreage to plant in South America is determined in order to satisfy the US market's demand for seed corn. An illustration of this is available in Figure 2.8 below:

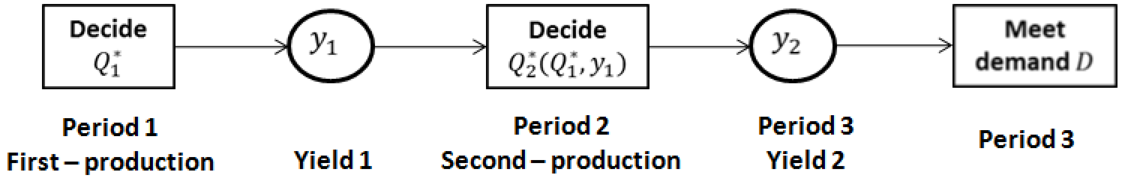


Figure 2.8 Seed Corn Three Period Production

During the first period, the firm must decide an appropriate land area to plant. At this point, the cost of production $c_1$is certain, but the yield from the land in production is uncertain. During the second period following the harvest of $Q_1$the yield Y_1 from the planted land area is obtained. The total seed available is equal to $Q_1 Y_1$. At this point, the firm compares the supply provided by $Q_1 Y_1$ with the expected demand for seed corn and determines if a second production period is necessary. If there is not enough seed corn available to meet the demand, the firm proceeds with the second production cycle and uses acreageQ_2. In Period 3, the firm estimates the expected yield Y_2 per acre in South America. Now the firm has a total seed corn quantity or supply $S = Q_1Y_1 + Q_2Y_2$ to offer for sale for that year. The demand, D is deterministic, and if the model predicts correctly, D should be met by the total S. Because the firm is seeking to maximize its profit, it makes sense that it would want to eliminate any surplus production. However, because the yields are random the firm cannot always avoid the surplus. Production is assumed to cost less in the first period than in the second period due to the increased cost of shipping seed corn from South America to the United States. Our data from Dow AgroSciences shows that the second production is 50% more expensive than the production in North America. Finally we note that the yields returned in the first and second period are considered to be independent.

Chapter 4

Monte Carlo Simulation Solution

To quantify the benefit of dual-production, we first solve the firm's problem assuming that the firm could produce the seed only once in the northern US, in Section 4.1. In Section 4.2, we solve the dual-production problem, and then compare the performances of the two production systems in Section 4.3.

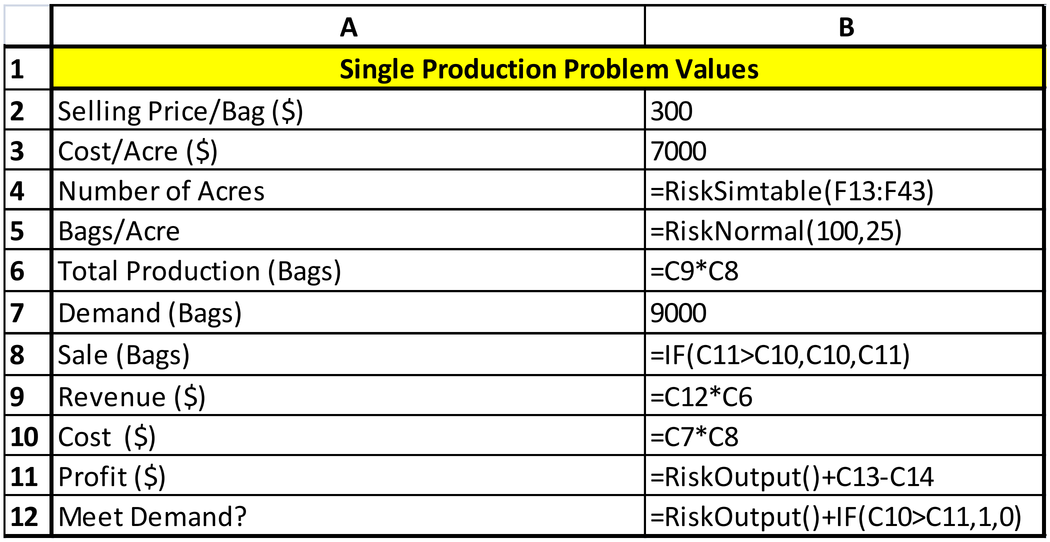
4.1 Base Model for Single Production

The scenario of growing seed corn only in the United States is considered first. This problem assumes a situation in which the company does not have access to a dual-production period. Once the single-period production problem is solved, we use the optimal acreage value from the single production to decide the best acreage to plant for the dual-production problem.

The analysis in this model uses Monte Carlo Simulations run using @Risk version 6 software developed and sold by the Palisade Corporation. Monte Carlo is a type of simulation that uses computerized mathematical techniques to account for the risk involved in quantitative decisions according to Palisade (2014). According to Weisstein

(2014), the Monte Carlo is particularly useful for use in cases when output numbers need to be obtained for problems that cannot be solved analytically. For each value that the model simulates, values are sampled randomly from the probability distributions that are inputted in into the model. Each time the values are sampled is called an iteration. These iterations provide an accurate result that shows the probability of a range of possible outcomes. This allows the Monte Carlo simulation to provide a comprehensive view for what may happen. The simulation also shows how likely each outcome is. For the analysis in this paper, each simulation was run for 10,000 iterations, to get an accurate view of the probability distribution. The model used is in Table 4.1 below:

Table 4.1 Single Productions Problem Formulas

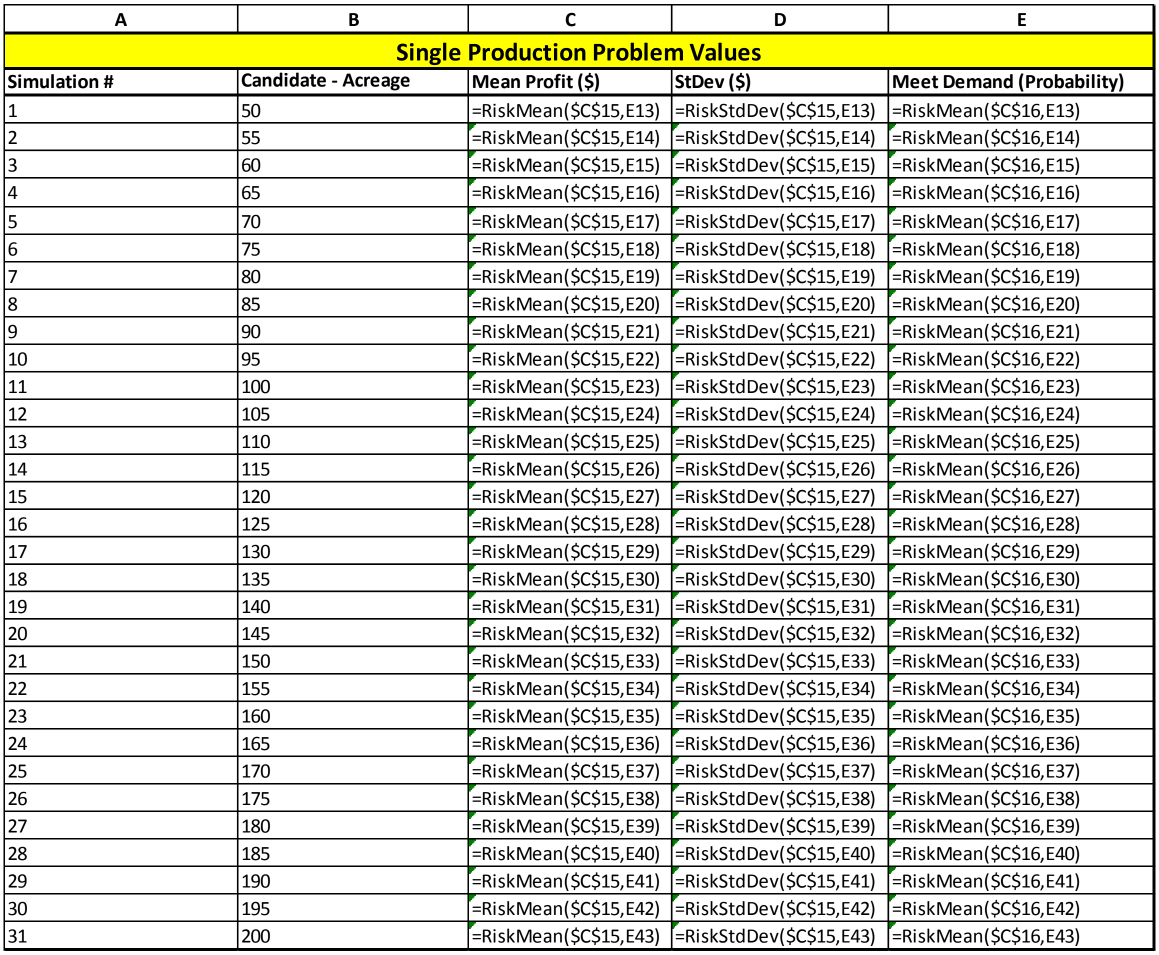


	A	B
1	**Single Production Problem Values**	
2	Selling Price/Bag ($)	300
3	Cost/Acre ($)	7000
4	Number of Acres	=RiskSimtable(F13:F43)
5	Bags/Acre	=RiskNormal(100,25)
6	Total Production (Bags)	=C9*C8
7	Demand (Bags)	9000
8	Sale (Bags)	=IF(C11>C10,C10,C11)
9	Revenue ($)	=C12*C6
10	Cost ($)	=C7*C8
11	Profit ($)	=RiskOutput()+C13-C14
12	Meet Demand?	=RiskOutput()+IF(C10>C11,1,0)

The given values in the model are in cell B2 price/bag value of $300, B3 cost/acre value of $7000, and B7 demand in bags of 9000. Cell B3, cost/acre, reflects all the costs associated with producing, transporting and processing, and preparing the corn for sale. The goal of the exercise is to maximize expected profit by adjusting the number of acres planted. B4 refers to a table of values for a Monte Carlo simulation. A set of reasonable values was examined to find acreage values that would maximize profit. There are 31 candidate values ranging from 50 acres – 200 acres in the “Candidate - Acreage” column of table 4.2. These are the cells referenced in cell B4 in Table 4.1. Cell B5, the bag yield per acre has a mean value of 100, with a standard deviation of 25 bags. The large standard deviation is a result of the high level of uncertainty due to variability in weather, disease, and other factors present in seed corn production. There are 80,000 seeds or approximately 1.2 bushels in each bag of seed.

A “Risknormal” function was used to generate random values on the normal distribution curve given the mean and standard deviation values. The total production, cell B6 is the number of bags/acre, B5 * the total acres planted, B4. Cell B8, the number of bags sold by the company is equal to the D if $S > D$ or to S if $D > S$. Revenue, cell B9, is equal to the number of bags sold * the selling price. Cost, cell B10, is equal to the total number of acres planted * the cost per acre. Cell B11, profit, is equal to revenue minus cost. Profit is made into an output and analyzed using a Monte Carlo simulation is determine the ideal number of acres to plant in order to maximize the profit. Cell B12, meet demand, is an “If” function used to determine if demand is met when the simulation is run. Cell B12 is referenced in Table 4.2. The Simulation equations used are in Table 4.2.

Table 4.2 Single Production Simulation Calculations

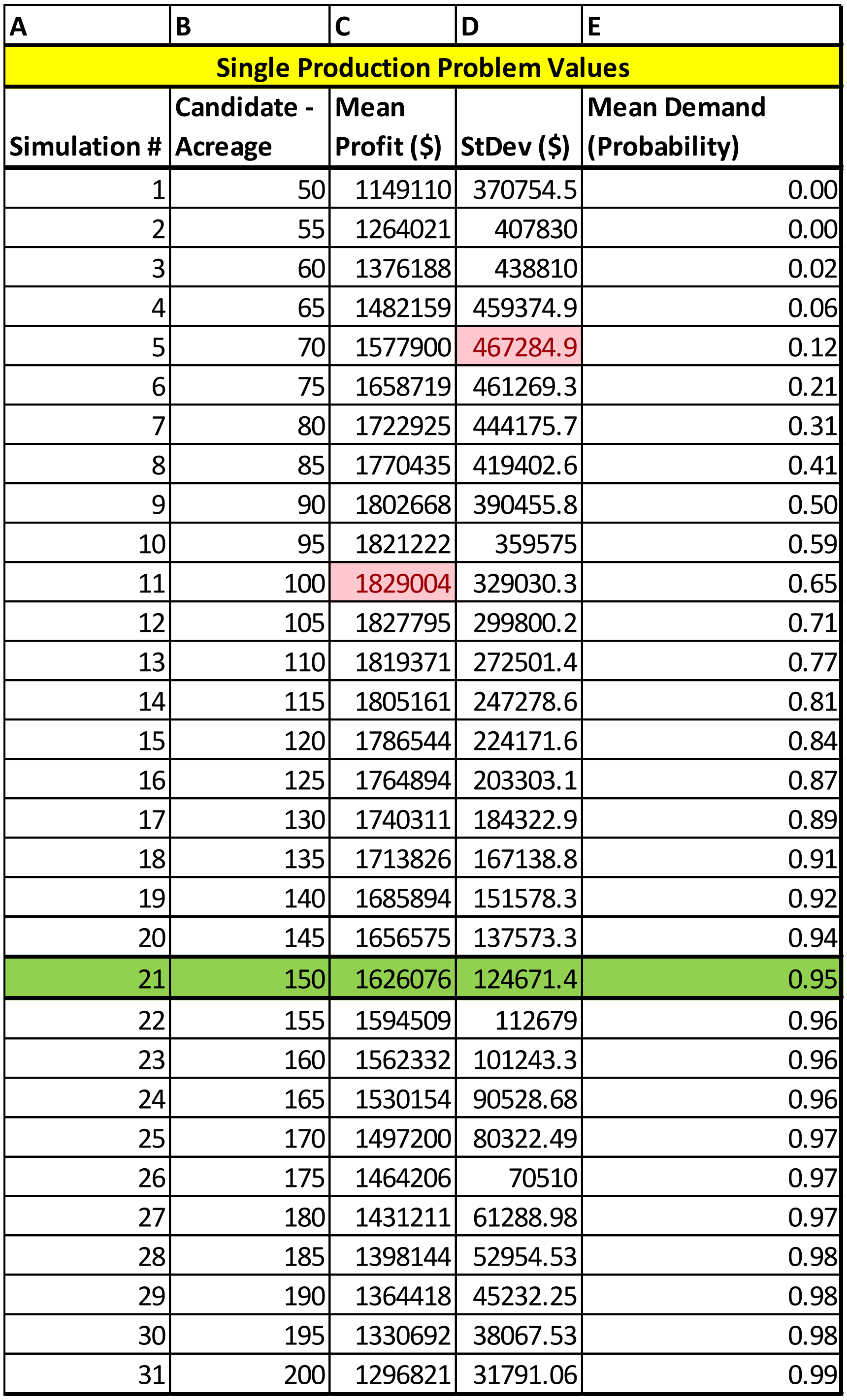


A	B	C	D	E
Single Production Problem Values				
Simulation #	**Candidate - Acreage**	**Mean Profit ($)**	**StDev ($)**	**Meet Demand (Probability)**
1	50	=RiskMean(C15,E13)	=RiskStdDev(C15,E13)	=RiskMean(C16,E13)
2	55	=RiskMean(C15,E14)	=RiskStdDev(C15,E14)	=RiskMean(C16,E14)
3	60	=RiskMean(C15,E15)	=RiskStdDev(C15,E15)	=RiskMean(C16,E15)
4	65	=RiskMean(C15,E16)	=RiskStdDev(C15,E16)	=RiskMean(C16,E16)
5	70	=RiskMean(C15,E17)	=RiskStdDev(C15,E17)	=RiskMean(C16,E17)
6	75	=RiskMean(C15,E18)	=RiskStdDev(C15,E18)	=RiskMean(C16,E18)
7	80	=RiskMean(C15,E19)	=RiskStdDev(C15,E19)	=RiskMean(C16,E19)
8	85	=RiskMean(C15,E20)	=RiskStdDev(C15,E20)	=RiskMean(C16,E20)
9	90	=RiskMean(C15,E21)	=RiskStdDev(C15,E21)	=RiskMean(C16,E21)
10	95	=RiskMean(C15,E22)	=RiskStdDev(C15,E22)	=RiskMean(C16,E22)
11	100	=RiskMean(C15,E23)	=RiskStdDev(C15,E23)	=RiskMean(C16,E23)
12	105	=RiskMean(C15,E24)	=RiskStdDev(C15,E24)	=RiskMean(C16,E24)
13	110	=RiskMean(C15,E25)	=RiskStdDev(C15,E25)	=RiskMean(C16,E25)
14	115	=RiskMean(C15,E26)	=RiskStdDev(C15,E26)	=RiskMean(C16,E26)
15	120	=RiskMean(C15,E27)	=RiskStdDev(C15,E27)	=RiskMean(C16,E27)
16	125	=RiskMean(C15,E28)	=RiskStdDev(C15,E28)	=RiskMean(C16,E28)
17	130	=RiskMean(C15,E29)	=RiskStdDev(C15,E29)	=RiskMean(C16,E29)
18	135	=RiskMean(C15,E30)	=RiskStdDev(C15,E30)	=RiskMean(C16,E30)
19	140	=RiskMean(C15,E31)	=RiskStdDev(C15,E31)	=RiskMean(C16,E31)
20	145	=RiskMean(C15,E32)	=RiskStdDev(C15,E32)	=RiskMean(C16,E32)
21	150	=RiskMean(C15,E33)	=RiskStdDev(C15,E33)	=RiskMean(C16,E33)
22	155	=RiskMean(C15,E34)	=RiskStdDev(C15,E34)	=RiskMean(C16,E34)
23	160	=RiskMean(C15,E35)	=RiskStdDev(C15,E35)	=RiskMean(C16,E35)
24	165	=RiskMean(C15,E36)	=RiskStdDev(C15,E36)	=RiskMean(C16,E36)
25	170	=RiskMean(C15,E37)	=RiskStdDev(C15,E37)	=RiskMean(C16,E37)
26	175	=RiskMean(C15,E38)	=RiskStdDev(C15,E38)	=RiskMean(C16,E38)
27	180	=RiskMean(C15,E39)	=RiskStdDev(C15,E39)	=RiskMean(C16,E39)
28	185	=RiskMean(C15,E40)	=RiskStdDev(C15,E40)	=RiskMean(C16,E40)
29	190	=RiskMean(C15,E41)	=RiskStdDev(C15,E41)	=RiskMean(C16,E41)
30	195	=RiskMean(C15,E42)	=RiskStdDev(C15,E42)	=RiskMean(C16,E42)
31	200	=RiskMean(C15,E43)	=RiskStdDev(C15,E43)	=RiskMean(C16,E43)

Table 4.2 shows the data and equations used for determining the most profitable and beneficial decision. Column A contains a list of numbers identifying each possible of the 31 possible simulations. Column B represents the acreage values associated with the simulation candidates analyzed. In column C, the RiskMean function is used calculate the mean profit expected for the associated candidate in column B. The calculation in column c uses the output values from cell B11 in table 4.1 to determine the expected mean profit. Column D analyzes the standard deviation for each profit value in column C. Column E

evaluates that probability that demand will be met. This is a measure of the percentage of times that the value in cell B12 of Table 4.1, “Meet Demand?” has a value of 1, indicating that demand is met.

Table 4.3 Single Production Problem Values



A	B	C	D	E
Single Production Problem Values				
Simulation #	Candidate - Acreage	Mean Profit ($)	StDev ($)	Mean Demand (Probability)
1	50	1149110	370754.5	0.00
2	55	1264021	407830	0.00
3	60	1376188	438810	0.02
4	65	1482159	459374.9	0.06
5	70	1577900	467284.9	0.12
6	75	1658719	461269.3	0.21
7	80	1722925	444175.7	0.31
8	85	1770435	419402.6	0.41
9	90	1802668	390455.8	0.50
10	95	1821222	359575	0.59
11	100	1829004	329030.3	0.65
12	105	1827795	299800.2	0.71
13	110	1819371	272501.4	0.77
14	115	1805161	247278.6	0.81
15	120	1786544	224171.6	0.84
16	125	1764894	203303.1	0.87
17	130	1740311	184322.9	0.89
18	135	1713826	167138.8	0.91
19	140	1685894	151578.3	0.92
20	145	1656575	137573.3	0.94
21	150	1626076	124671.4	0.95
22	155	1594509	112679	0.96
23	160	1562332	101243.3	0.96
24	165	1530154	90528.68	0.96
25	170	1497200	80322.49	0.97
26	175	1464206	70510	0.97
27	180	1431211	61288.98	0.97
28	185	1398144	52954.53	0.98
29	190	1364418	45232.25	0.98
30	195	1330692	38067.53	0.98
31	200	1296821	31791.06	0.99

The values calculated using the Monte Carlo simulation are displayed in Table 4.3. Figure 4.1 is a graphical representation of these findings. The mean profit increases with acreage values until a maximum value of $1,829,004 was reached. This can be observed in Table 4.3 above at the 100 acre level, as well as the graphical representation in Figure 4.1. The profit increases represents the supply increasing until the full demand is met. When all demand is met, profit begins to drop as more costs are incurred through the planting of additional acres, and the additional supply remains unsold. The standard deviation (StDev) values also follow a pattern, increasing from the beginning value of 0 to the peak value of $467,285 at 70 acres of production. The initial increase is due to the fact that more acres are being planted, giving greater variability in possible total yields. Following the maximum value found at 70 acres, standard deviation values begin to decrease as acreage increases. This is due to the fact that it becomes less likely that demand will remain unmet as acreage increases. At a certain point, the standard deviation values begin to approach 0. At some point above 200 acres of production, the standard deviation value will be 0. Supply will always meet demand in the case, but profit will be far reduced from its maximum value.

Also analyzed above in the “Meet Demand” column is the probability that demand is met in full for each candidate acreage level. This is important to determine, because it gives the decision-makers at the seed corn firm a “service level” value that they can base judgments on. The service level, or probability of satisfying consumer demand increases as acreage increases until it reaches 100%. However, increasing service level results in a decrease in short-term profit. Each industry has different service-level standards, and each company must determine what service level to use. In the case of seed corn, a major selling point that brings consumers back is a high service level. Farmers need to ensure that they will be able to purchase seed. Therefore for this problem, a service level of 95% is reasonable. Making the assumption that the firm wants to ensure that demand will be met in 95% of cases, it must grow the acreage specified in the Candidate column that corresponds to a value of at least 0.95. This requires the firm to increase production from 100 to 155 acres, and results in a loss of $234,634 to increase the service level from 66% to 95%.

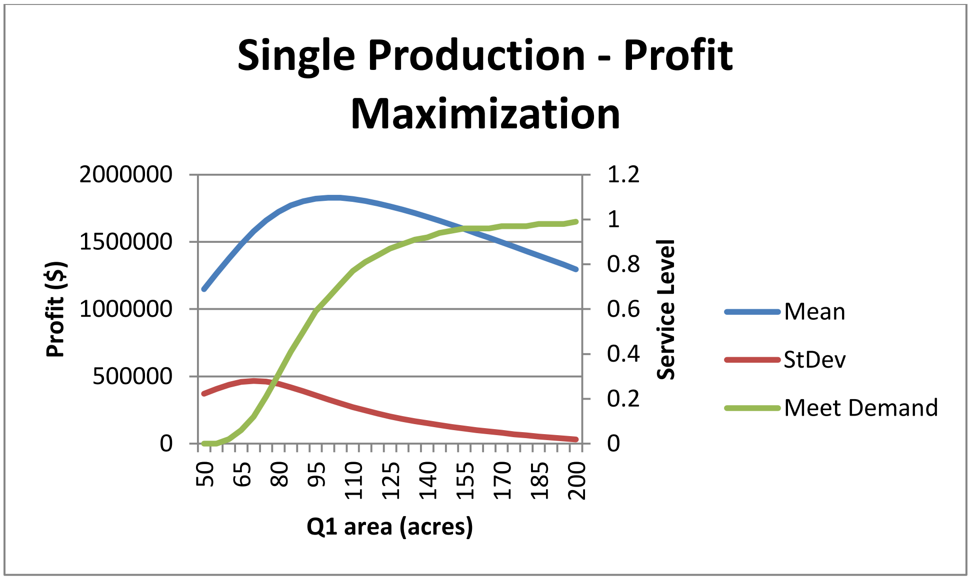
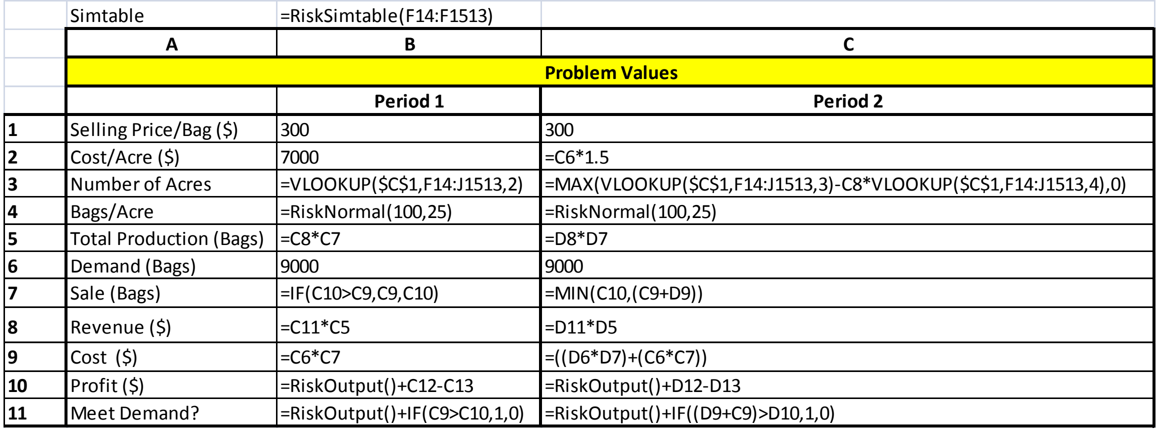


Figure 4.1 Single Production Profit Maximization

4.2 Analysis of Dual-Period Production

A similar process is completed for dual-period production with the simulation setup specifis to dual-production. In Table 4.3, column C contains the details for the second production. Cell C1 contains the selling price of seed. Cell C6 contains the demand. Cell C2, cost per acre, is equal to the 1.5 times the cost per acres in first production. This increment reflects increased transportation and logistics costs. The candidate solutions (2100 of them) for the Dual period production are shown in Table 4.4. they are inputted using a risksimtable function. A VLookup function is used in cell C3 to select the number in the table corresponding to the simulation number being analyzed. This allows all 2100 simulations possibilities to be analyzed sequentially, and reduces drudgery and manual input into the model. Cell C4, C5, C7, C8, C9, C10, and C11 use the same equations as those used in the single production period.

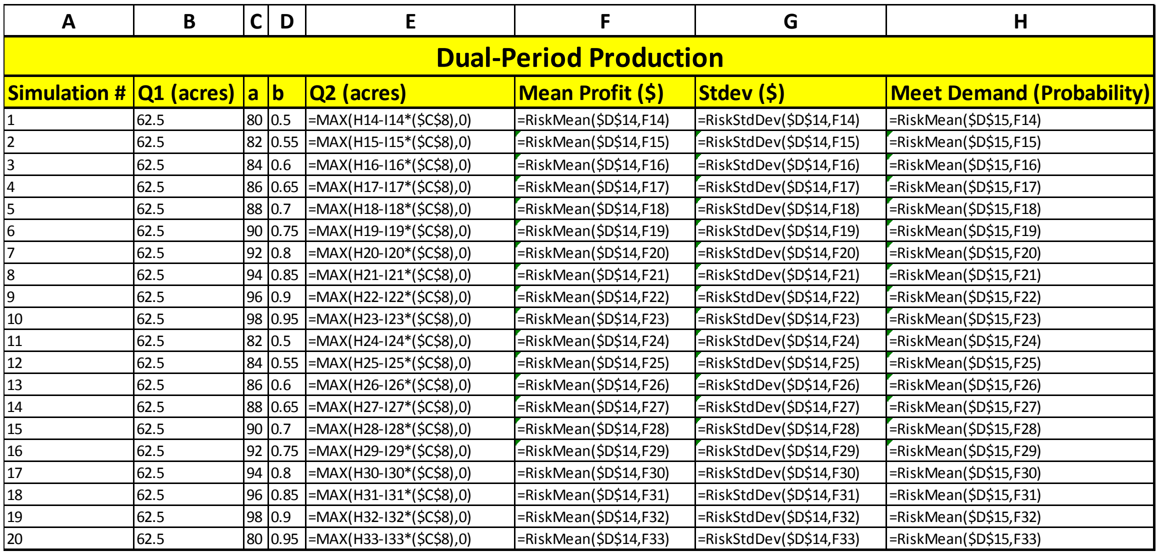
Table 4.4 Dual Period Problem Formulas



	Simtable	=RiskSimtable(F14:F1513)	
	A	B	C
	Problem Values		
		Period 1	Period 2
1	Selling Price/Bag ($)	300	300
2	Cost/Acre ($)	7000	=C6*1.5
3	Number of Acres	=VLOOKUP(C1,F14:J1513,2)	=MAX(VLOOKUP(C1,F14:J1513,3)-C8*VLOOKUP(C1,F14:J1513,4),0)
4	Bags/Acre	=RiskNormal(100,25)	=RiskNormal(100,25)
5	Total Production (Bags)	=C8*C7	=D8*D7
6	Demand (Bags)	9000	9000
7	Sale (Bags)	=IF(C10>C9,C9,C10)	=MIN(C10,(C9+D9))
8	Revenue ($)	=C11*C5	=D11*D5
9	Cost ($)	=C6*C7	=((D6*D7)+(C6*C7))
10	Profit ($)	=RiskOutput()+C12-C13	=RiskOutput()+D12-D13
11	Meet Demand?	=RiskOutput()+IF(C9>C10,1,0)	=RiskOutput()+IF((D9+C9)>D10,1,0)

In Table 4.4, Column A uses provides a number identrifiaction for each simulation. Column B, diplays Q_1 acreage values from the first period production. Based on previous experimentation and intuition, a range of Q_1values was determined that would capture the optimal solution with dual-period production. 22 Q_1 values ranging from 62.5 acres to 112.5 acres were examined in 2.5 acre demonimations. In column B, a represents the value of acreage to be planted in the second period if the the first period yield, Y_1 is equal to 0. Ten values are used for a, ranging from 80 – 98. In column C, b represents the demand divided by period one acreage, $b = {}^{D}/_{Q_1}$. There are ten values examined for b, ranging from 0.5 – 0.95. In column E, the second period acreage, Q_2 is determined. The equation $Q_2 = a + b(Q_1)$ is used to determine the expected acreage Q_2 from the second production period.

Table 4.5 Dual Period Production Simulation Calculations



A	B	C	D	E	F	G	H
Dual-Period Production							
Simulation #	Q1 (acres)	a	b	Q2 (acres)	Mean Profit ($)	Stdev ($)	Meet Demand (Probability)
1	62.5	80	0.5	=MAX(H14-I14*(C8),0)	=RiskMean(D14,F14)	=RiskStdDev(D14,F14)	=RiskMean(D15,F14)
2	62.5	82	0.55	=MAX(H15-I15*(C8),0)	=RiskMean(D14,F15)	=RiskStdDev(D14,F15)	=RiskMean(D15,F15)
3	62.5	84	0.6	=MAX(H16-I16*(C8),0)	=RiskMean(D14,F16)	=RiskStdDev(D14,F16)	=RiskMean(D15,F16)
4	62.5	86	0.65	=MAX(H17-I17*(C8),0)	=RiskMean(D14,F17)	=RiskStdDev(D14,F17)	=RiskMean(D15,F17)
5	62.5	88	0.7	=MAX(H18-I18*(C8),0)	=RiskMean(D14,F18)	=RiskStdDev(D14,F18)	=RiskMean(D15,F18)
6	62.5	90	0.75	=MAX(H19-I19*(C8),0)	=RiskMean(D14,F19)	=RiskStdDev(D14,F19)	=RiskMean(D15,F19)
7	62.5	92	0.8	=MAX(H20-I20*(C8),0)	=RiskMean(D14,F20)	=RiskStdDev(D14,F20)	=RiskMean(D15,F20)
8	62.5	94	0.85	=MAX(H21-I21*(C8),0)	=RiskMean(D14,F21)	=RiskStdDev(D14,F21)	=RiskMean(D15,F21)
9	62.5	96	0.9	=MAX(H22-I22*(C8),0)	=RiskMean(D14,F22)	=RiskStdDev(D14,F22)	=RiskMean(D15,F22)
10	62.5	98	0.95	=MAX(H23-I23*(C8),0)	=RiskMean(D14,F23)	=RiskStdDev(D14,F23)	=RiskMean(D15,F23)
11	62.5	82	0.5	=MAX(H24-I24*(C8),0)	=RiskMean(D14,F24)	=RiskStdDev(D14,F24)	=RiskMean(D15,F24)
12	62.5	84	0.55	=MAX(H25-I25*(C8),0)	=RiskMean(D14,F25)	=RiskStdDev(D14,F25)	=RiskMean(D15,F25)
13	62.5	86	0.6	=MAX(H26-I26*(C8),0)	=RiskMean(D14,F26)	=RiskStdDev(D14,F26)	=RiskMean(D15,F26)
14	62.5	88	0.65	=MAX(H27-I27*(C8),0)	=RiskMean(D14,F27)	=RiskStdDev(D14,F27)	=RiskMean(D15,F27)
15	62.5	90	0.7	=MAX(H28-I28*(C8),0)	=RiskMean(D14,F28)	=RiskStdDev(D14,F28)	=RiskMean(D15,F28)
16	62.5	92	0.75	=MAX(H29-I29*(C8),0)	=RiskMean(D14,F29)	=RiskStdDev(D14,F29)	=RiskMean(D15,F29)
17	62.5	94	0.8	=MAX(H30-I30*(C8),0)	=RiskMean(D14,F30)	=RiskStdDev(D14,F30)	=RiskMean(D15,F30)
18	62.5	96	0.85	=MAX(H31-I31*(C8),0)	=RiskMean(D14,F31)	=RiskStdDev(D14,F31)	=RiskMean(D15,F31)
19	62.5	98	0.9	=MAX(H32-I32*(C8),0)	=RiskMean(D14,F32)	=RiskStdDev(D14,F32)	=RiskMean(D15,F32)
20	62.5	80	0.95	=MAX(H33-I33*(C8),0)	=RiskMean(D14,F33)	=RiskStdDev(D14,F33)	=RiskMean(D15,F33)

For each of the 2100 candidate solution, we ran the simulation. Columns F, G, and H, represent Mean Profit, Standard Deviation, and Service Level. These values are calculated the same way as in the single-production period.

Each Q_1value was simulated 100 times with a range of 10 a values and 10 b values. This gave 100 alternative Mean profit values for each Q_1 value used. In order to create a useful graph, each set of 100 Q_1values was analyzed using a conditional formatting tool to determine the highest mean profit value among the 100 combinations. This yielded 22 Mean Profit values with corresponding standard deviation and meet demand values that showed the range of optimal solutions for each Q_1 value. These values and their respective Standard deviations, and meet demand/service levels were graphed. These are below in Figure 4.2. These lines follow a similar curve to those found in the first production period. The optimal value is 82.5 acres for Q_1, and a Q_2 value of $Q_2 = a + b(Q_1)$. This provides a value of $1,956,610 in profit with a standard deviation of $203,725. To achieve a 95% service level, the firm will be require to plant 112.5 acres for Q_1, and 4 acres for Q_2, which will cause a loss of $96,118 in mean profit.

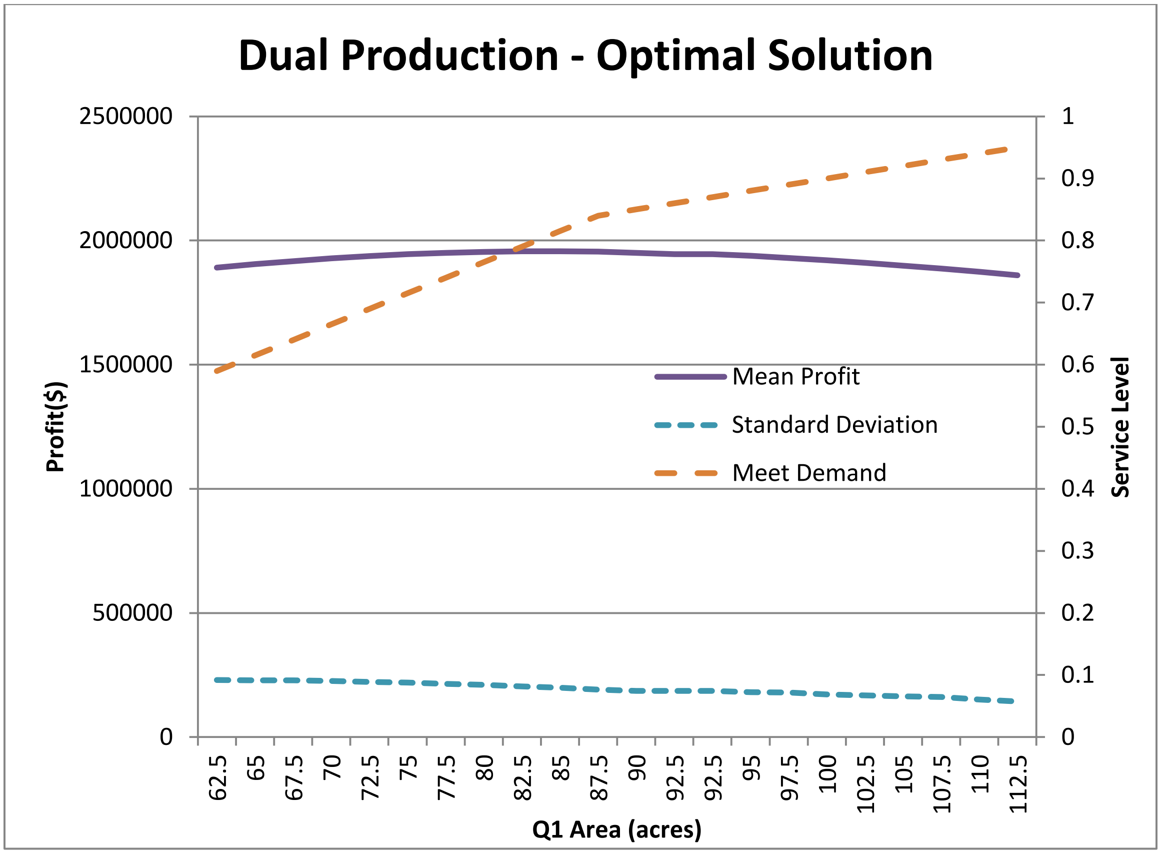
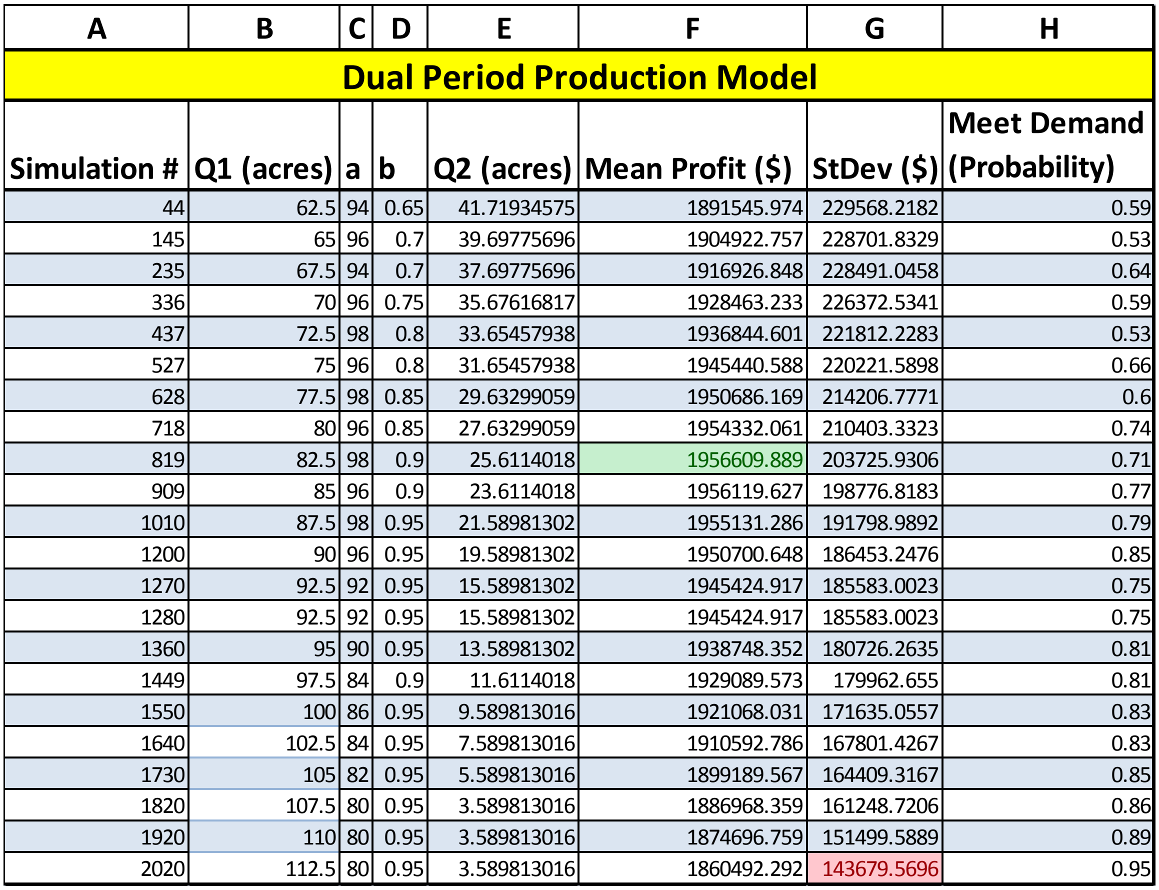


Figure 4.2 Dual Production – Optimal Solution

Table 4.6 Dual Period Production Simulation Values



A	B	C	D	E	F	G	H
Dual Period Production Model							
Simulation #	**Q1 (acres)**	**a**	**b**	**Q2 (acres)**	**Mean Profit ($)**	**StDev ($)**	**Meet Demand (Probability)**
44	62.5	94	0.65	41.71934575	1891545.974	229568.2182	0.59
145	65	96	0.7	39.69775696	1904922.757	228701.8329	0.53
235	67.5	94	0.7	37.69775696	1916926.848	228491.0458	0.64
336	70	96	0.75	35.67616817	1928463.233	226372.5341	0.59
437	72.5	98	0.8	33.65457938	1936844.601	221812.2283	0.53
527	75	96	0.8	31.65457938	1945440.588	220221.5898	0.66
628	77.5	98	0.85	29.63299059	1950686.169	214206.7771	0.6
718	80	96	0.85	27.63299059	1954332.061	210403.3323	0.74
819	82.5	98	0.9	25.6114018	1956609.889	203725.9306	0.71
909	85	96	0.9	23.6114018	1956119.627	198776.8183	0.77
1010	87.5	98	0.95	21.58981302	1955131.286	191798.9892	0.79
1200	90	96	0.95	19.58981302	1950700.648	186453.2476	0.85
1270	92.5	92	0.95	15.58981302	1945424.917	185583.0023	0.75
1280	92.5	92	0.95	15.58981302	1945424.917	185583.0023	0.75
1360	95	90	0.95	13.58981302	1938748.352	180726.2635	0.81
1449	97.5	84	0.9	11.6114018	1929089.573	179962.655	0.81
1550	100	86	0.95	9.589813016	1921068.031	171635.0557	0.83
1640	102.5	84	0.95	7.589813016	1910592.786	167801.4267	0.83
1730	105	82	0.95	5.589813016	1899189.567	164409.3167	0.85
1820	107.5	80	0.95	3.589813016	1886968.359	161248.7206	0.86
1920	110	80	0.95	3.589813016	1874696.759	151499.5889	0.89
2020	112.5	80	0.95	3.589813016	1860492.292	143679.5696	0.95

4.3 Comparison of Single and Dual Production Scenarios

The data from both the single and dual-period production was graphed on Figures 4.3, 4.4, and 4.5 below.

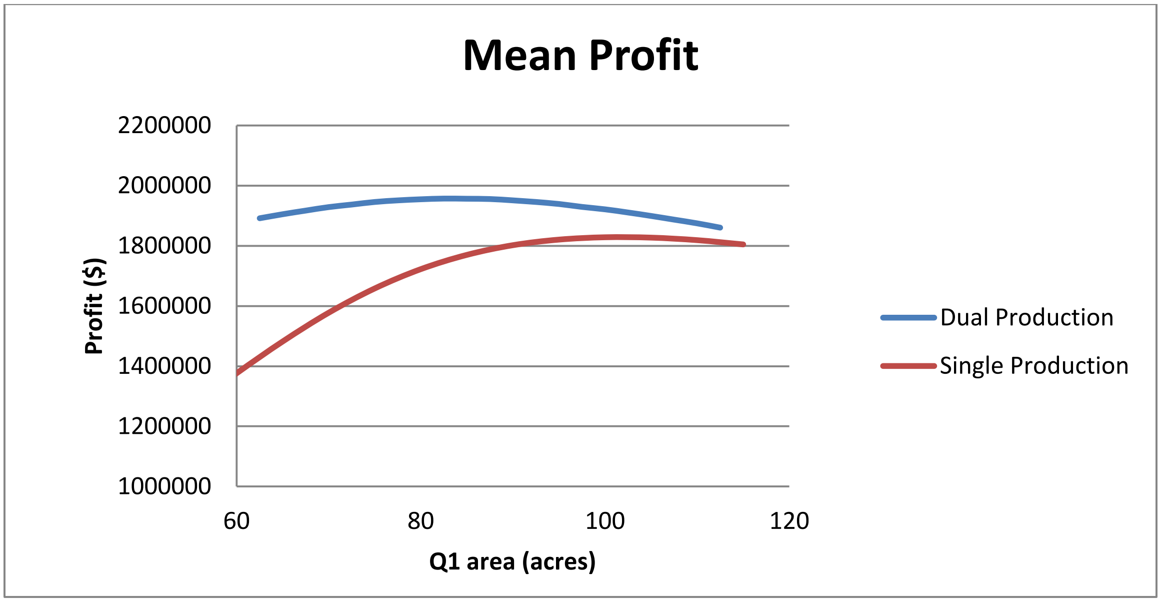


Figure 4.3 Single and Dual Production Mean Profit

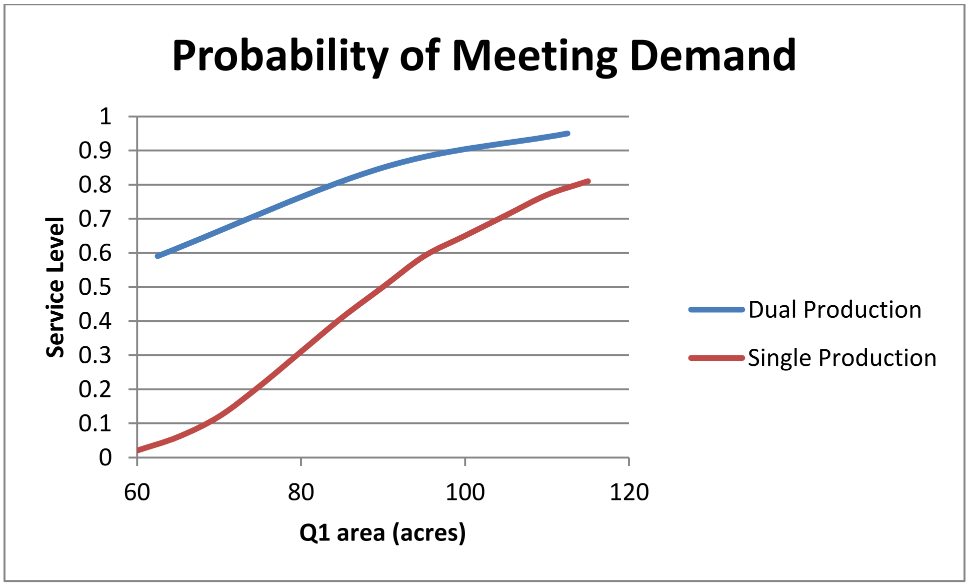


Figure 4.4 Single and Dual Production Probability of Meeting Demand

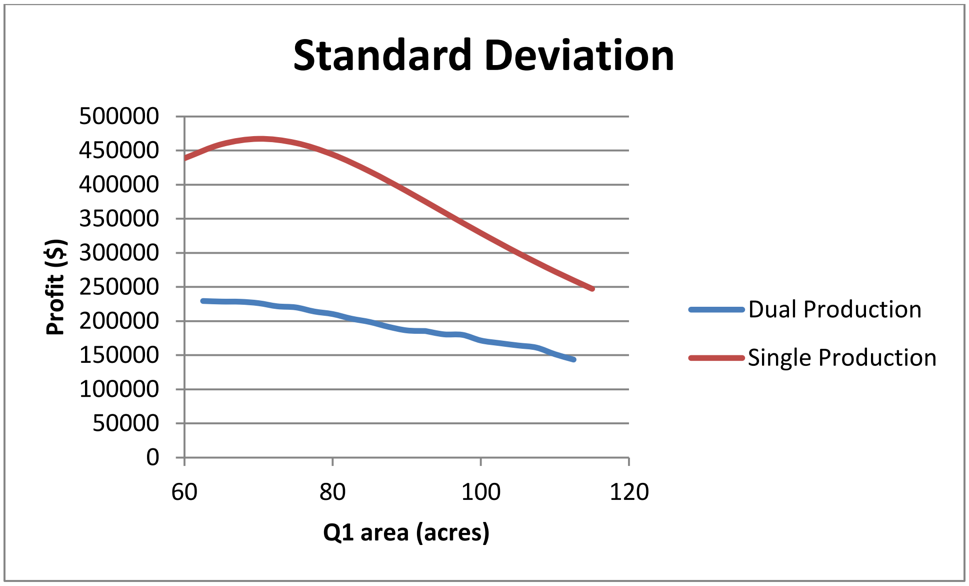


Figure 4.5 Single and Dual Production Standard Deviation

From a visual analysis, it is apparent that the dual-production has a higher profit and a lower standard deviation at its optimal value at the peak of the curve. When the numbers are examined, it shows that the optimal single period production value is $1,829,004 with a standard deviation of $329,030 with a service level of 65% while the optimal dual production period value is $1,956,610 with a standard deviation of $203,726 with a service level of 71%. Therefore, the dual production period outperforms the single period in all respects. The optimal dual-period solution shows an increase of 7.0 % in profitability, and a decrease of 38.1% in standard deviation. The service level increases by 6%. If the optimal values are determined at a 95% service level, or a Meet demand value of 0.95, the dual-period solution shows an increase of 14.4% in profitability but also displays a 15.2% increase in standard deviation.

Chapter 5

Summary

In this paper, we considered a sequential seed corn production problem. This is the problem of determining the optimal land area to plant when the yield from the land is variable. In order to provide context the process for producing, maintaining, and harvesting seed corn was explained, and the equipment used was discussed. We first solved a single-period problem in which all the demand must be satisfied by one single planting and harvest in North America. We solved this problem using @Risk version 6 software to run Monte Carlo simulations.

Using the optimal solution from the single period problem, a two production period problem was solved using an extended model to find an optimal solution for planting seed corn in the United States, followed by South America. The paper covered the Monte Carlo Simulation model used for analyzing the problem and data.

Our key finding was that using a two production period model with the optimal Monte Carlo simulation would increase profit by 7% over a single period production using a Monte Carlo Simulation. A decrease of 38% in standard deviation was also realized. This research is useful for the seed corn industry because it offers a 7% increase in profitability, and allows managers to quickly model possible outcomes for both single and dual production given production constraints. The speed that the @Risk version 6 model analyzes data is very beneficial to a large seed corn producer that is required to determine the optimal acreage for hundreds seed corn varieties.

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ACADEMIC VITA

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EDUCATION

The Pennsylvania State University – Schreyer Honors College
University Park, PA
College of Agricultural Sciences Expected
Graduation: May 2014
Bachelor of Science, Agricultural Systems Management
Minors: International Agriculture, Environmental Resource Management, Off-Road Equipment
Specializations: Business Analytics, Systems Optimization, Precision Agriculture, Agricultural Technology, Food Security

Summary: Entrepreneur with over 9 years of experience; Studied/Researched abroad in India, Spain, Kenya, Vietnam, Cambodia, and Thailand; Trained in crisis management as an EMT; Proven ability in strategy implementation, marketing, and management

LEADERSHIP AND EXPERIENCE

U.S. Department of State Critical Language Scholarship Program - Urdu, Lucknow, India
May 2012 – Present
<u>Two-Time Scholarship Recipient and Alumni Ambassador</u>
- Received highly competitive scholarship (acceptance rate ~15%) from US State Dept. two consecutive summers
- Studied Urdu at intensive immersion program at American Institute of Indian Studies in Lucknow, India 6/12-8/12, 6/13-8/13
- Selected as one of two alumni ambassadors to recruit students through social media, presentations, and information sessions

Clean Cut Landscaping Service, Glenside, PA March
2005 – Present
<u>Founder & Owner</u>
- Started a lawn care business that has provided excellent, quality service to 50+ loyal clients of 8+ years
- Created and executed marketing strategies for a wide range of services, including lawn care, mulching, snow removal,
and property management consulting

- Supervised, trained, and coordinated work schedules for three employees each working 20-30 hours per week, successfully managing the business remotely while at school
- Performed billing, quarterly and annual tax calculations and payments

NEWBio USDA Research Assistant , University Park, PA
August 2012 – Present
Research Assistant
- Conducted international research on accidents/hazards related to power equipment in bio-energy production for USDA NEWBio initiative.
- Conducted on-site research at CENER in Navarra, Spain, January 2013
- Compiled research into a paper presented at ASABE NABEC conference, July 2013

Penn State University Ambulance Service, University Park, PA
August 2010 – Present
Career EMT-B
- Provided emergency pre-hospital care in stressful environments, handling 100-150 emergencies per year
- Trained 25 volunteers in patient care, radio communication, emergency driving, and mass casualty response
- Certified as a PA EMT-B after taking 180 hour course in Emergency Medicine at Thomas Jefferson University
- Earned Certifications in: International Trauma Life Support (ITLS), Tactical Emergency Medicine (TEMS), and Emergency Vehicle Operator's License (VFIS EVOC)
- Built on 2 years of experience as a volunteer EMT-B for Second Alarmers Rescue Squad in Willow Grove, PA

Penn State International Agriculture Club
August 2012 – Present
Vice President
- Coordinated logistics and agendas
- Implemented outreach/growth policies causing club to go 5 members to 25 members in 8 months.

SKILLS AND HONORS

- *Languages*: Intermediate-Advanced Urdu/Hindi, Intermediate Spanish
- *Computer*: Microsoft Office Suite, Quicken Suite
- *Publications:* "A Technical Review on Safety in On-Farm Biomass Production and Storage Systems"- July 2013
  "Biomass Systems Optimization in the Northeastern US – A Case Study" – Expected April 2014
- *Honors:* Inducted into Gamma Sigma Delta Agricultural Honor Society – March 2013
  1st Place Milking the Rhino International Competition – December 2012