Fertilizer Use, Crop Yield, and Expected Production

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Abstract

The rapidly growing population and required future food supply is a concern to be addressed now. Understanding which fertilizers can produce the maximum value is an important factor in addressing this issue. This study is a statistical analysis of varying fertilizer applications for a conventional corn crop and the resulting crop yields. Four types of fertilizers are examined; Urea, NPK, NPK/Urea combination and Ammonium-sulfate/Urea combination. Data was gathered from the Russell Ranch Sustainable agriculture farm in Davis, California. The range of data is from 1994 to 2007 and includes 49 crop yields. We predict that the NPK/Urea combination fertilizer will produce the largest average crop yield. An expected benefit value equation is used to determine which fertilizer application on conventional corn crop produces the largest crop yield. The analysis results in NPK/Urea combination fertilizer producing the largest expected production or benefit value. The results contribute to the factors of production for greater crop yields. However, this is not the only factor to be considered when addressing future food demand. Alternate studies are needed in the areas of population growth, economic sustainability, agricultural sustainability and water management to produce a complete picture of future needs. Complications of our study include a limited amount of data. In order to yield the best analysis a greater database is needed in the area of fertilizer use and crop production.

Introduction

The human population is increasing exponentially which indicates that there is going to be higher demand for food and resources that are needed for human basic needs (www.worldback.org). Farmers in the future will need to produce more food to satisfy the peoples' and food corporations' demands. Our project was initially about finding the best combination of irrigation system and fertilizers that allows for the maximization of corn crop yields. Since every external input was considered to be constant, same irrigation system, quantity and quality of water, soil water capacity, temperature, humidity, and rainfall, we focused more on fertilizer use. The synthetic fertilizers used in Russell Ranch varied but the ones used the most were NPK, Urea, and combinations of NPK and Urea and Ammonium-sulfate (A-S) and Urea.

Fertilizers provide nutrients to plants that allow them grow faster and stronger resulting into higher yields. Fertilizers have a great impact in conventional agriculture and often they are ratified for high crop yields (Sepirl 77). On the other hand, if bad managing of fertilizers is practiced, they will have negative impacts on the environment and society. They are often blamed for polluting surface and groundwater, emitting Green House Gasses, degrading soil fertility, and are linked to human respiratory problems. The problem is not the fertilizer itself but rather its application on the fields, remember, all things in moderation. Better fertilizers management and decision making techniques can lead to a better relationship between fertilizers and the environment. This manifesting that negative impacts by synthetic fertilizers can be reduced and finding out which fertilizer provides the necessary nutrients for a strong plant growth and mastering its management in a more environmentally sound manner, could result into less contaminated planet.

There are other practices and disciplines in agriculture, such as the use of organic fertilizers, water efficient irrigation systems, crop rotation, biological and cultural pest control, polyculture, small scale farms, community supported agriculture, community foods, and direct sale, which leads to a sustainable agricultural system. Moving towards sustainable agriculture is something that could be considered when trying to reduce the contamination due to synthetic fertilizers. In the same way, more research should be done towards sustainable agriculture for findings about sustainable agriculture being capable to provide the same crop yields to support the planet's fast growing population.

Objective

Given that the population is increasing at an exponential rate, and the subsequent exponential increase in the demand for food resources, we aim to determine what the most effective fertilizer is that produces the greatest crop yield. In order to arrive at this conclusion we first fulfil several tasks:

- Obtain and categorize crop yield data from Russell Ranch.
- Filter through the data to retain only data sets for the three fertilizers in question: Urea, NPK, Ammonium Sulfate, and a combination of these.
- Analyze data and perform calculations using probability trees under the Expected Value method.

Once we have successfully completed the tasks above, we then proceed to draw conclusions based on our calculations.

To complete the task of obtaining and categorizing crop yield data from Russell Ranch, we used their online database. Included in their database are data sets specific to a search query. For our purposes we extracted data for corn crop yields. We looked at machine harvested crops for all available raw data years. Further, we were tasked with filtering the data provided to retain only data pertinent to our research. The data set we obtained included instances of empty data and fertilizers that were of no relevance in our research. Finally, all data was categorized and arranged according to fertilizer, or combination of fertilizers, and subsequently filtered so as to retain only available data for fresh corn yields.

Finally, the data was analyzed using the Expected Value model. In order to determine which fertilizer was most effective, we had to make sense of the data at hand. Due to the nature of the data and the objective of our research, the best suited means to reach our objective was to implement the Expected Value analysis method. Through this method we analyze the data and come up with an expected value for a given input. In our case we were looking for the Expected Production for corn fertilizers. The results of this analysis were to be compared to one another. Whichever variable yielded the greatest benefit value would mean that the fertilizer was expected to produce the most crop yield. Therefore, we analyzed each possible fertilizer and combination of fertilizers and compared the benefits of each. As a result we were able to identify the combination of Urea and NPK to be the most efficient crop fertilizer as it resulted in the highest crop yield.

Hypothesis

If NPK/Urea combination fertilizer is applied to a conventional corn crop, it will produce the largest crop yield on average.

Data Sources

1.) Agricultural Sustainability Institute (2013). Russell Ranch Sustainable Facility. *Data*. <http://russellranch.metro.ucdavis.edu/> (Dec.3, 2013).

2.) The World Bank (2013). Population Growth (annual %). *Data.* <http://data.worldbank.org/indicator/SP.POP.GROW> (Dec 3. 2013).

3.) Serpil, Savci. (2012). “An Agricultural Pollutant: Chemical Fertilizer.” *International Journal of Environmental Science and Development.* 3(1), 77. Web.

Methods and Assumptions

To determine which fertilizer, or combination of fertilizers, results in the greatest crop yield, we used statistical analysis through probability trees and the Expected Value method.

We begin by calculating the marginal probability, which is the probability that an individual, or combination of fertilizers, is used. We do this by creating a ratio of the number of plots that used a specific fertilizer, or combination of fertilizers, to the total number of plots. Our research data included a total of 49 plots using Urea, NPK, Ammonium Sulfate, or a combination of each.

Next, we found the minimum and the maximum fresh crop yield. The minimum and maximum yields were used to calculate the range for our research entries. By taking the difference between the minimum and maximum values, and distributing that value in three range sections, we are able to quantify the size of the crop yield of a given fertilizer. The average of these three range sections is then used to calculate the Expected Production values.

We then proceed to calculate the conditional probability, the probability of corn yield depending on the type of fertilizer used. For this calculation we take the frequency of each yield in a given range section and divide by the frequency of the given fertilizer use. For instance, we are given a frequency of 8 for NPK out of the 49 total plots. Within NPK there is a frequency of

0, 6, and 8 per each respective range section. The ratio of the frequency of the use of NPK to the frequency of NPK at each range section is the conditional probability.

Further, we calculate the relative frequency, that is, the proportion of a fertilizer yielding a certain amount of corn. This is the result of the product between the conditional probability and the marginal probability for each given fertilizer, or fertilizers.

Finally we calculate the expected production values. These are weighted averages that take into consideration the product of the relative frequencies and the average crop yield per range section. The sum of each value at each range section is the expected production value. Upon analyzing the results, we conclude that a given fertilizer, or fertilizers, is the most effective in producing the greatest crop yield based on which returned the largest expected production value.

In analyzing our data and computing our values we adhere to a set of assumptions for the scope of our research. We assume that the weather is variable, the soil used in all plots is the same, and that the crops are irrigated with an equal amount of water. These assumptions help preserve the scope of our research and data analysis within the reach of this project.

Calculation/Results

The results were the following:

Fertilizers (Y) and Crop Yields (X).

Probabilities of combined or individual fertilizers happening. (Marginal Probability).

Pr {NPK} =*8/49* Pr {Urea} =*9/49 Pr* {Urea and NPK} = *23/49* Pr {ammonium-sulfate and urea} =*9/49*

Total plots= 49

Fresh Crop Yields (lbs. /acre)	**Average (lbs. /acre)**
A). 7,300 – 9,333	*8,316.5*
B). 9,334 – 11,367	*10,350.5*
C). 11,368 – 13,400	*12,384*

Probabilities of corn yield depending on fertilizer used (Conditional Probability).

Pr{A|NPK }=*0/8*	Pr{A|Urea}=*5/9*	Pr{A|Urea&NPK}=*0/23*	Pr{A|A-S&Urea}=*2/9*
Pr{B|NPK }=*6/8*	Pr{B|Urea}=*4/9*	Pr{B|Urea&NPK}=*8/23*	Pr{B|A-S&Urea}=*6/9*
Pr{C|NPK}=*2/8*	Pr{C|Urea}=*0/9*	Pr{C|Urea&NPK}=*15/23*	Pr{C|A-S&Urea}=*1/9*

Proportion of certain fertilizer yielding certain amounts of corn (Relative Frequency).

Pr{x,y}=Pr{Y=y}*Pr{X=x|Y=y}

Pr{NPK,A|NPK}=(8/49)*(0/8)=*0*

Pr{NPK, B|NPK }=(8/49)*(6/8)=*0.123*

Pr{NPK, C|NPK }=(8/49)*(2/8)=*0.041*

Pr{Urea,A|Urea&NPk}=(23/49)*(0/23)=*0*

Pr{Urea,B|Urea&NPk}=(23/49)*(8/23)=*0.163*

Pr{Urea,C|Urea&NPk}=(23/49)*(15/23)=*0.310*

Pr{Urea, A|Urea }=(9/49)*(5/9)=*0.102*

Pr{Urea, B|Urea }=(9/49)*(4/9)=*0.082*

Pr{Urea, C|Urea }=(9/49)*(0/9)=*0*

Pr{A-S&Urea,A|A-S&Urea}=(9/49)*(2/9)=*0.041*

Pr{A-S&Urea,B|A-S&Urea}=(9/49)*(6/9)=*0.123*

Pr{A-S&Urea,C|A-S&Urea}=(9/49)*(1/9)=*0.020*

Expected Production (This is an average).

For NPK:

SUM=[{(0)*(8,316.5)}+{(0.123)*(10,350.5)}+{(0.410)*(12,384)}]=1,780.86 lbs./acre

For Urea:

SUM=[{(0.102)*(8,316.5)}+{(0.082)*(10,350.5)}+{(0)*(12,384)}]= 1,697.02 lbs./acre

For Urea & NPK:

SUM=[{(0)*(8,316.5)}+{(0.163)*(10,350.5)}+{(0.310)*(12,384)}]= 5,526.17 lbs./acre

For A-S & Urea:

SUM=[{(0.041)*(8,316.5)}+{(0.123)*(10,350.5)}+{(0.020)*(12,384)}]= 1861.77 lbs./acre

Total Expected Production= 10,865.81 lbs./acre

		Joint Prob.	*Avg. Expected Productivity*	*Benefits (Lbs./acre)*
Pr{NPK} (8/49)	Pr{A|NPK} (0/8)	*0*	*8,316.5*	*0*
	Pr{B|NPK} (6/8)	*0.123*	*10,350.5*	*1,273.11*
	Pr{C|NPK} (2/8)	*0.041*	*12,384*	*507.74*
Pr{Urea} (9/49)	Pr{A|Urea} (5/9)	*0.102*	*8,316.5*	*848.28*
	Pr{B|Urea} (4/9)	*0.82*	*10,350.5*	*848.74*
	Pr{C|Urea} (0/9)	*0*	*12,384*	*0*
Pr{Urea&NPK} (23/49)	Pr{A|Urea&NPK} (0/23)	*0*	*8,316.5*	*0*
	Pr{B|Urea&NPK} (8/23)	*0.163*	*10,350.5*	*1,687.13*
	Pr{C|Urea&NPK} (15/23)	*0.31*	*12,384*	*3,839.04*
Pr{A-S&Urea} (9/49)	Pr{A|Urea&NPK} (2/9)	*0.041*	*8,316.5*	*340.98*
	Pr{B|Urea&NPK} (6/9)	*0.041*	*10,350.5*	*1,273.11*
	Pr{C|Urea&NPK} (1/9)	*0.02*	*12,384*	*247.68*
	Total:	1		10,865.81

Findings:

-Combinations of fertilizers resulted in higher yields.

-On average NPK yielded in the ranges of 10,350.5 and 12384 lbs./acres.

-On average Urea had lower yields than NPK, ranging from 8,316.5 to 10,350 lbs./acre.

-On average Urea and NPK combined had higher yields than NPK ranging in the same parameter of 10,350.5 and 12,384 lbs./acres but skewing to the left.

-Ammonium-Sulfate and Urea combined on average yielded 10,350.5 lbs./acre. It seems that the yields of Ammonium-Sulfate and Urea combined cover a larger range, 8,316.5 to 12,384 lbs./acre.

Conclusions

We confirmed our hypothesis with this statistical analysis of data. NPK/Urea combination fertilizer produced the largest expected crop yield on average. This combination fertilizer produced within the range of 10,350.5 and 12,384 pounds of crop per acre, resulting in the highest range of the four examined fertilizers. Ammonium-sulfate/Urea combination fertilizer resulted in higher average yields but not as consistently. This data is useful for determining which fertilizer will produce the greatest corn crop yield. This data is also limited and could benefit from a greater amount of data per fertilizer type and corresponding crop yield. Further research is required to produce the most reliable results.

Our research on fertilizer use and crop yield contributes to a larger picture of the future human population and food demand. Fertilizers will likely play an important role in conventional farming and food demand for expansive populations. The question of how will we feed a rapidly expanding population is not only addressed by which fertilizer will produce the greatest yield but by many factors combined. Research on the expected population growth will be important in determining how much food will need to be produced. Research has already been conducted in this area with a variety of expectations of future population numbers ranging from a pessimistic to an optimistic view of growth. Economic analysis is also needed on the cost effectiveness of each fertilizer. Each fertilizer will need to be addressed concerning availability, ease of attainability, transportation and storage, as well as the cost of application. Cost-benefit analysis will likely play an important role in determining the possible outcomes of future food demand and production.

Sustainable agriculture practices analysis can contribute to the long-term view of population growth and food production. Analysis of the short-term and long-term environmental impacts, organic and synthetic fertilizer use, and fertilizer toxicity can contribute to the best management of our resources as the population requires more food. Resource management is crucial the health and availability of resources. Water management is also an important factor for population growth and food production. Research on the required water per fertilizer, the impacts of fertilizers on water quality and methods of irrigation per crop and fertilizer will help contribute to a complete analysis of the future needs of the global population. As we look to study in these areas and continue research on fertilizer use and crop yield the most important resource will be the amount of data we are able to utilize. Data availability will determine the quality of our research results. Funding and support of places like the Russell Ranch Sustainable Agriculture farm is needed to carry out research in all of the mentioned areas.

Recommendations and Limitations

While performing research and data analysis we encountered a few limitations. For instance, we were faced with incomplete data in our fertilizer crop yield data sets. We were also limited to data from machine harvested plots, not inclusive of hand-harvested plots. For future research, now that we have established that a combination of NPK and Urea result in greatest crop yields, we recommend focusing on water quality and management, as well as food source planning and agriculture. Further research in the fields of food management and sustainable agriculture could yield results in different types of fertilizers and organic alternatives to produce large crop yields with minimum environmental impact. Research in water management and water quality can also be highly beneficial as it can indicate which types of fertilizer can result in the same or larger crop yields using the least water and the resulting water quality.