Weather Derivatives in Russia: Insuring Farmers Against Temperature Fluctuations

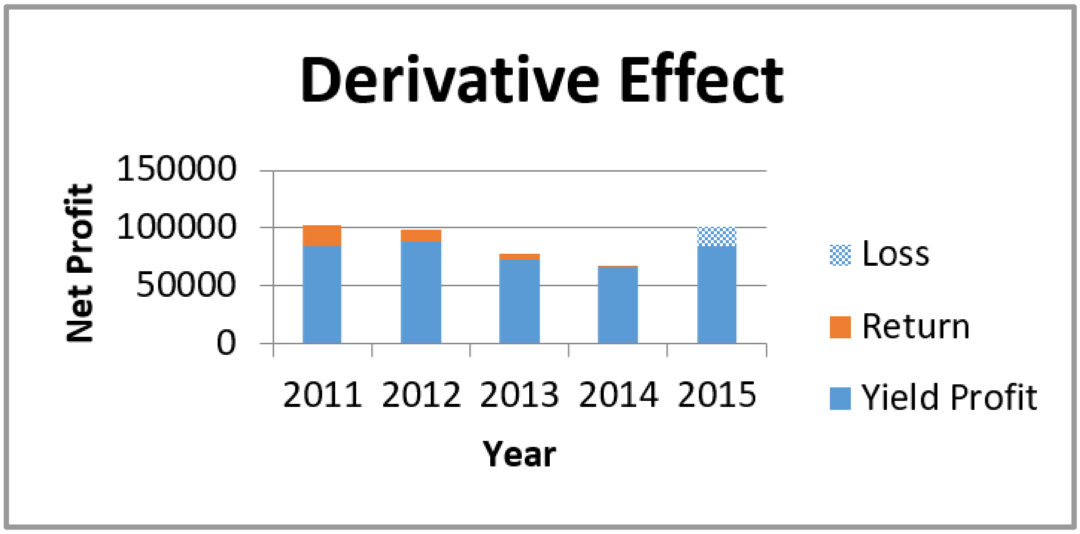

Figure 1. Derivative Effect for Farmers

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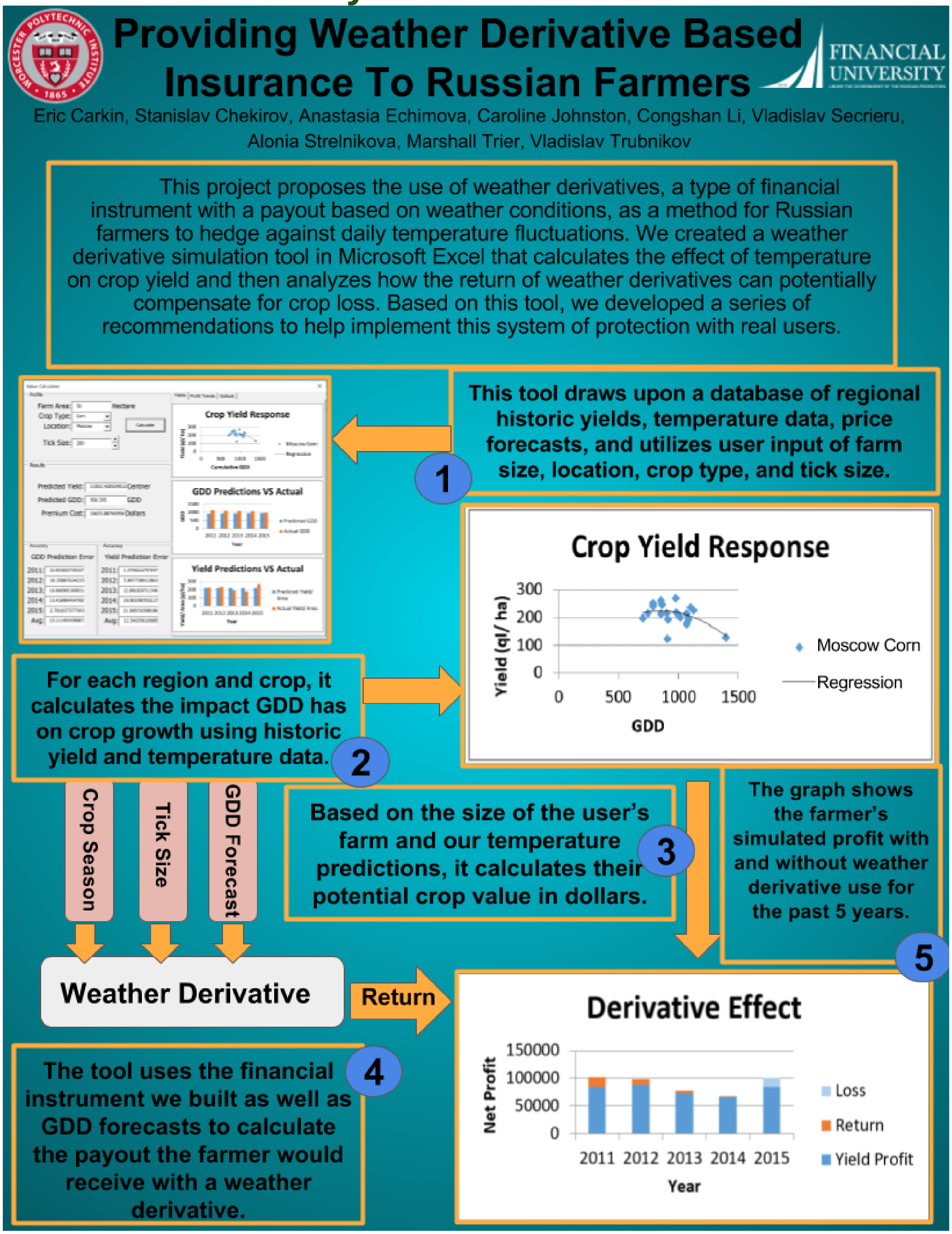
Abstract

This project proposes the use of weather derivatives, a type of financial instrument with a payout based on weather conditions, as a method for Russian farmers to hedge against daily temperature fluctuations. We created a weather derivative simulation tool in Microsoft Excel that calculates the effect of temperature on crop yield and then analyzes how the return of weather derivatives can potentially compensate for crop loss. Based on this tool, we developed a series of recommendations to help implement this system of protection with real users.

Executive Summary



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1. Utilizing Weather Derivatives in Russia

In 1998 it was estimated that 20% of the world economy is vulnerable to weather conditions (Barrieu & Scaillet, 2010). Weather is one of the most uncontrollable and influential variables within the agriculture sector, becoming increasingly unpredictable as climate change continues to affect global weather patterns. In some cases, extreme weather can cause up to a 40% deficit in crop yields in Russia, potentially devastating a farmer's economic income (Pavlova, Varcheva, Bokusheva, & Calanca, 2014). However, by utilizing various types of insurance, those in the agricultural sector are able to survive and continue to develop by mitigating their exposure to this financial risk.

Russia's ambitions to become agriculturally self-sufficient and the country's ban on imported crops have caused its agricultural sector to grow substantially in recent years (Liefert, Serova and Liefert, 2015). In order to foster this growth and continue to develop this sector, farmers are in need of insurance policies to protect themselves from risks that are beyond their control, such as weather. Weather derivatives, a type of financial option, can be used to protect farmers from daily fluctuations in temperature and precipitation that catastrophic insurance plans do not shield them from (Chung, 2011). These events have a modest effect over a single day but cumulatively they can have severe effects on a farmer's yield by the end of the growing season. Though weather derivatives have been used to hedge against risks in other countries, Russia has yet to explore this tool and popularize it among its farmers (Esper Group, 2010).

The goal of this project is to create a proof-of-concept weather derivatives pricing system. This system will explore the feasibility of insuring farmers within Russia using such financial instruments. Farmers will be able to hedge against weather-related risks by trading weather derivative options and to remain financially stable even in times of fluctuating weather conditions. In order to accomplish this goal, we had to meet the following objectives:

1. Determine the relationship between temperature and crop yields within the Moscow, Krasnodar, and Omsk regions (see Figure 2)
2. Price weather derivative options
3. Create an Excel tool to simulate the financial impact of weather derivatives for users

Figure 2. Regions of focus: Left-Krasnodar, Center-Moscow, Right-Omsk

2. Using Weather Derivatives to Insure Russian Agriculture

In order to implement a weather derivatives system within Russia, one must understand the relationship between weather and agriculture and the current measures in place to protect farmers against weather risks. In this chapter we will explain the concept of a weather derivative as a means to hedge against these risks. Then we will discuss Russia's current agricultural economy and strategies to protect those working in agriculture from losses due to weather events.

2.1. Weather Risks and Mitigation Strategies

Weather conditions directly affect an estimated 20% of the world economy. The associated economic risks tied to weather can be divided into two major groups: high frequency-low risk events and low frequency-high risk events. Low frequency-high risk events, such as tornadoes and hurricanes, have an extreme, immediate impact, costing millions of dollars in damages. High frequency-low risk events are everyday weather phenomena, such as rain and temperature change. These events cause little impact over a single day but cumulatively can cause substantial, negative effects. The agricultural sector is especially sensitive to this type of risk, causing weather to have a considerable effect on the economy (Barrieu & Scaillet, 2010).

Governments across the globe have set up various forms of insurance, such as government subsidies or weather derivatives, to protect those working within the agricultural sector. The use of government subsidies in times of poor harvest however is not always ideal or even feasible for less developed countries that cannot generate enough revenue from taxation. Additionally, subsidy compensation is based on a farmer's exact loss, requiring insurers to determine farmer's yields in order to calculate what compensation is due. This increases costs to the insurer and in turn raises the cost of premiums for those who are insured (Chung, 2011).

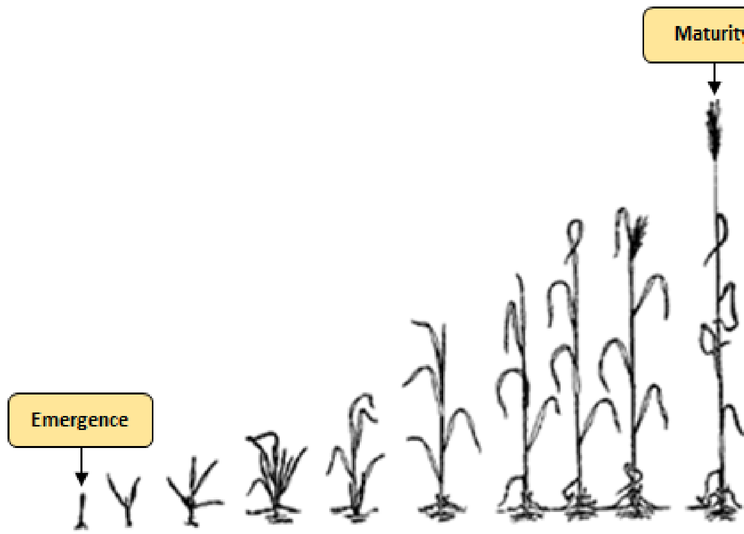
2.2. Weather Derivatives

Weather derivatives offer advantages to both small-scale farmers and corporate agricultural businesses. These derivatives are a type of option with an index-based payout, modeled after predicted future weather conditions over a certain period of time. The major difference between a weather derivative and subsidy is that the payout for a derivative is based on the specific weather conditions that cause farming loss, while a payout for a subsidy is based on the actual loss itself. Thus, weather derivatives are able to cover the high frequency-low risk events described above- without the need for insurers to determine farmer's exact yields, keeping premium costs lower (Chung, 2011).

There are still many adversities to overcome in order to utilize weather derivatives effectively (Chung, 2011). For example, as discussed above, a substantial amount of meteorological data is required to price the derivative with any degree of accuracy.

Collecting this data can take an enormous amount of time and resources but is absolutely vital for constructing an accurate index for making weather predictions.

Around 75% of all weather derivative transactions are based upon temperature predictions while 10% are based upon rainfall (Barrieu & Scaillet, 2010). Temperature-indexed weather derivatives revolve around the concept of Growing Degree Day (GDD), which measures heat accumulation to predict favorable plant development rates and stages of growth (see Figure 3, Appendix A). The metric below computes the difference between realized temperatures to a baseline temperature, which varies depending on the crop species (e.g. baseline temperature is 7.2 °C for potatoes, 4.4 degrees °C for wheat, etc.).



Days after emergence	12	15	23	28	34	38	41	45	85
Cumulative GDD	170	230	430	500	690	810	895	990	2260

Figure 3. Adapted from Growth and Development Guide for Spring Wheat (Simmons, Oelke and Anderson, 1985)

2.3. Non-Russian Weather Derivatives Systems

While weather derivatives are still a fledgling concept, being first traded on the Chicago Mercantile Exchange (CME) in 1999, their use is slowly becoming more commonplace within global markets outside of Russia (Barrieu & Scaillet, 2010). The Canadian agricultural insurance market recently introduced weather derivatives to insure against abnormal season temperatures or precipitation levels. After interviewing 397 farmers from Saskatchewan over a period of three years, investigators showed that 307 of these farmers used only traditional agricultural insurance, 37 only used weather derivatives, and 37 used both types of insurance. The study concluded that this wide disparity in weather derivative use is mainly attributed to farmers' lack of "awareness and understanding" of the tool (Van Camp, 2015, para. 5). About half of the participants who did not invest in weather derivatives were not aware that such a tool was available to them. About one-third of these farmers felt they did not have enough knowledge and skill to utilize the derivative (Van Camp, 2015).

In 2003, a Mumbai insurance company implemented weather derivatives for small groundnut and castor farmers in four villages within the Andhra-Pradesh state. The program encouraged farmers to attend educational workshops about the product to properly inform farmers of what this insurance is and its benefits, increasing the derivative's approachability. In 2005 after more improvements to the program, "more than 250000 [sic] farmers bought weather insurance" (Barrieu & Scaillet, 2010, 7). This pilot weather derivatives project in India was deemed a major success and inspired many more weather-based insurance schemes across India such as the Weather-based Crop Insurance Scheme (WBCIS) (Ministry of Finance of India, 2017).

One of the main distinctions between the Indian and the Canadian weather derivatives program is the presence of an educational program for the users. Equipped with the knowledge of how these weather derivatives could financially support them, farmers in India widely supported the weather derivatives system. However, those in Canada struggled to see the potential benefits of these tools or were completely unaware of them. Thus, in order to build a successful and accessible weather derivative system, it is vital to **educate the users**.

2.4. Agriculture in the Moscow, Krasnodar, and Omsk Regions

The Russian agriculture sector employs 7.7 million people, or 12% of the total workforce (British Potato Council, 2006). Concurrently, most of Russia's land mass is considered to be in "risky farming zones," where the harvest capacity, or these farmers' economic livelihoods depends largely on weather conditions. This is exacerbated by global climate change, which makes weather conditions increasingly more unpredictable. Because of the country's geographic span, the overall climate of Russia varies significantly from north to south and east to west, allowing different crops to thrive in different areas and temperatures (Country Studies, 1996). These differences in temperature not only affect the rate at which these crops grow, but also the dates on which they are planted and harvested, creating a unique set of growing conditions for each crop in each region.

Wheat, corn, and potatoes are three of the most widely-grown crops within Russia (Basic Element, 2013). Grains occupy more than 50% of the available cropland, primarily in the form of wheat (Country Studies, 1996). The overall land productivity is recently on the rise due to a decrease in the price of the ruble and recent favorable growing conditions (see Figure 4) (Medetsky, 2016). These large yields have brought in a substantial income for farmers, but again, only on the condition of favorable weather conditions. Thus, the agricultural sector is currently a lucrative investment area but not without potential risks.

The Moscow, Krasnodar, and Omsk regions provide a representative range of Russian climatic and agricultural conditions. The Moscow region is located in the western part of the country. Because of its large population, its local agriculture has a high profile. Krasnodar is the economic center of southern Russia, and 42.8% of its main industries is agriculture-based (Oleynik ,2013). Because of Krasnodar's geolocation by the Black Sea, the region has a longer growing season and more ideal weather conditions for plant growth (State's executives of the Krasnodar Region, n.d.). Conversely, the growing conditions in Omsk are not as favorable. Situated on the West Siberian Plain, the annual average temperature in Omsk is around 1.4°C (Climatemp, n.d.). Wheat, corn, and potatoes are grown in all three areas, but each is subject to the region's unique weather conditions.

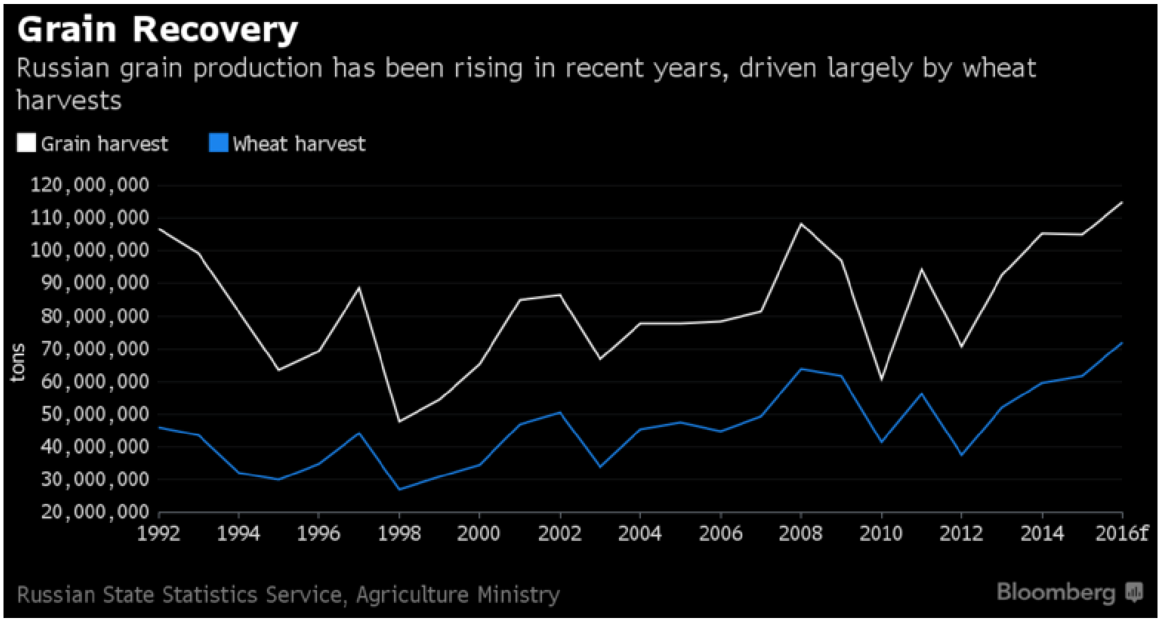


Figure 4. Russian grain production 1992-2016 (Medetsky, 2016)

2.5. The Shortcomings of the Russian Government Subsidies System

Government subsidies are currently used to help farmers in Russia hedge against weather risks (Buckley, 2017). State-issued subsidies have created significant growth within the agricultural sector, but not without complications. Some farmers cannot afford premiums, cannot meet land acreage requirements, or do not have the necessary accounting paperwork to qualify for these payments. In the 2012 drought, state compensation was only given to farmers "located in emergency districts… in a manner that was not at all transparent [to the farmers]," while those located in "non-emergency" zones suffered terrible losses as well (Ukhova, 2013, 12). Those who received payment received dismally insufficient amounts of compensation in comparison to their actual loss. The amount of red tape and underperformance from subsidies has resulted in a general lack of faith in the system (Ukhova, 2013). To work towards restoring this faith and efficiency, farmers must be able to easily access their method of compensation and understand why they are receiving it. Even with these improvements, subsidies only protect against high-impact events such as a drought. There is still a clear lack of protection against small but continual risk such as temperature fluctuations (Esper Group, 2010).

2.6. Conclusion

Weather derivatives can be used to insure farmers against daily fluctuations in temperature, which can have a substantial impact on their yields, and thus their wallets. Most of the farmland within Russia is highly sensitive to weather conditions. Though government subsidies have been used in the past to assist farmers in protecting themselves against weather risks, farmers no longer trust this specific system. Weather derivatives, however, use objective weather data and minimal bureaucratic procedures to help farmers compensate for their losses incurred by unfavorable weather conditions. As shown in the Indian and Canadian contexts, for the concept of a weather derivative to work it has to be familiar to farmers, and it is vital that they are educated about this tool's use and benefits. This builds trust and extends the use of an effective weather derivatives system.

3. Methodology: Developing a Weather Derivatives System

The goal of this project is to create a proof-of-concept weather derivatives pricing system. This system will explore the feasibility of insuring farmers within Russia using such financial instruments. As can be seen in Figure 5, we created the following objectives to successfully reach this goal:

1. Determine the relationship between temperature and crop yield within the Moscow, Krasnodar, and Omsk regions
2. Price weather derivative options
3. Create an Excel tool to simulate the financial impact of weather derivatives for users

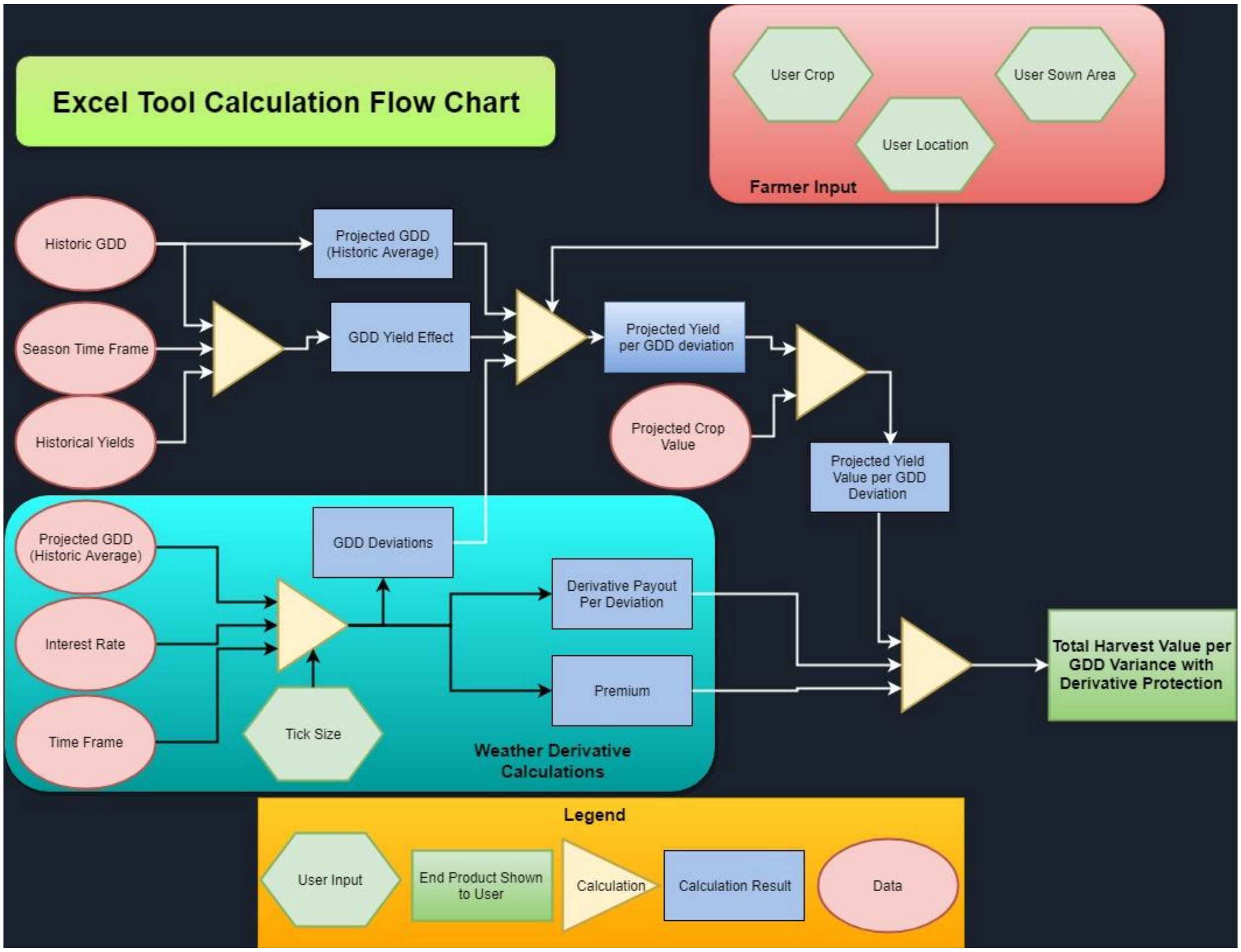


Figure 5. Methodology strategy layout

3.1. Determining Relationship between Temperature and Crop Yield

Because the pricing of weather derivatives depends upon GDDs that are crop-specific, we selected 3 regions and 3 specific crop types for the construction of derivatives. We identified corn, potatoes, and wheat (spring and winter) as some of the most common crops in Russia and the Moscow, Krasnodar, and Omsk regions as areas representing a spread of weather conditions. We gathered each crop's baseline temperature for its GDD calculation, its planting dates, and its harvest dates. Using these dates and temperatures, we were able to accurately gauge the temperatures these crops experience within a growing season.

We calculated the mean cumulative GDD experienced by each crop within Moscow, Krasnodar, and Omsk regions from the years 1996 to 2015 with data from the meteo.ru (RIHMI-WDC) weather database and collected regional crop yield statistics from Knoema, another online database (see References). Using Microsoft Excel, we developed a database of these temperatures and implemented an ordinary least squares regression technique to quantify the relationship between cumulative GDD over the growing period and crop yield.

3.2. Pricing Weather Derivatives

In order to price the derivatives, we surveyed various pricing methods. After reviewing literature by Sun and van Kooten (2015); Groll, López-Cabrera, and Meyer-Brandis (2016); Taylor and Buizza (2006); Chung (2011); Alaton, Djehiche, and Stillberger (2002); Barrieu and Scaillet (2010); and Consedine (2000), we chose the historical burn analysis method, which takes the average historical GDD as the expected GDD for future years (see Appendix A). This technique was chosen because of its ability to accurately model these future GDD values, the accessibility of the data needed for this method, and the ability to conduct the necessary mathematical processes in a familiar format such as an Excel spreadsheet.

3.3. Creating Simulation Tool

To visually represent the results of this project and demonstrate the potential impact of this weather derivatives system, we created a weather derivative simulation tool in Visual Basic for Excel. This tool calculates the potential losses a farmer faces by interfacing with the GDD/yield relationship model. The farmer inputs his or her farm size, crop type, and location. His or her projected yield for the upcoming year is then calculated by utilizing the appropriate GDD/yield model, the projected GDD based on his or her region, and the size of his or her farm. This yield is then multiplied by the estimated worth of his or her crop, data gathered from Bloomberg, converting his or her potential profit to a monetary value (see Figure 6).

Based on the GDD/yield model, the tool also estimates potential economic loss if the weather varies from the expected GDD. A derivative is then constructed using the chosen tick size. The derivative's payoff can be compared to a farmer's potential loss, showing its potential effectiveness as a form of insurance.

The tool draws upon values from the database mentioned in Section 3.1. Because all of the data inputs (excluding those provided by the user) are contained within Excel spreadsheets, the tool can be easily updated to include more recent information or different areas and crops, expanding it to become a more encompassing and accurate tool.

3.4. Conclusion

The cumulative application of our methods is showcased in the simulation tool. The tool is capable of evaluating the GDD/yield relationship for each region and crop, the predicted GDD values for future years, and the potential profit or loss with weather derivative use for a specific user. This allows the user to directly visualize the effect of a weather derivative and its potential as an insurance measure. Additionally, the tool is easily modifiable, allowing it to remain relevant and open for modification while further developments take place in this research field. By using this tool, those who are interested in developing derivative-based insurance can also test their own research methods and display these techniques to their target users.

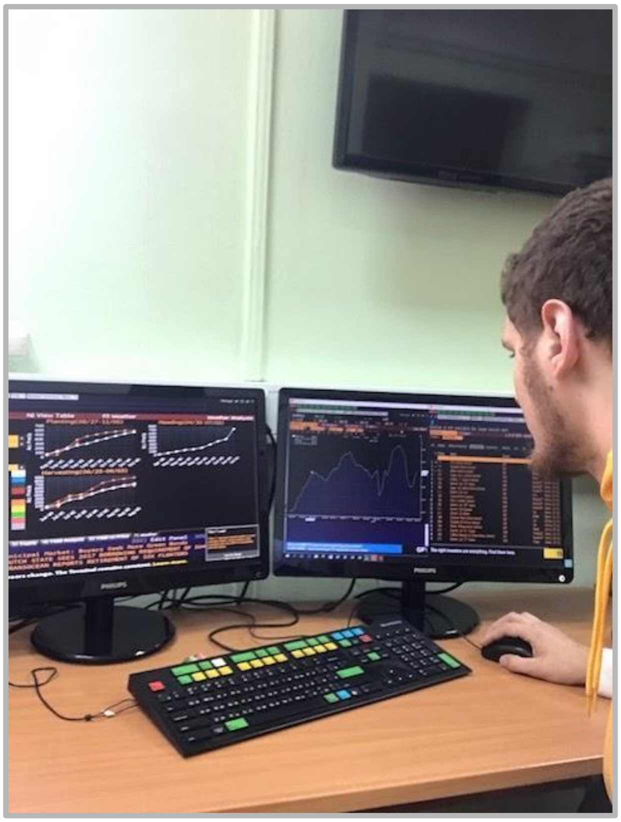


Figure 6. Collecting data from the Bloomberg Terminal

4. Results and Discussion

After initial poor results in our regression analysis for cumulative GDD and crop yield, we found there were large flaws in the methods in which we were processing and interpreting our collected data. We then developed a strategy to correct these flaws to pre-process our data to eliminate trends that were contaminating our results. This lead to more accurate results. We produced a clearer relationship between the two variables. When pricing the derivative, the historical burn analysis generated high quality GDD predictions and generally low premiums for the farmers. Both the regression and the pricing calculations were implemented in our Excel simulation tool that is both flexible for those who wish to build upon it and approachable for farmers who wish to use it.

4.1. Determining Relationship between Temperature and Crop Yield

The regression between temperature and crop yield initially yielded fairly weak results and no clear or logical relationship has been obtained at that point (see Figure 7). After discussing the quality of our data, we isolated the causes of this weak regression result to two factors:

1.) Qualitative growing season data
2.) Skewed yield data

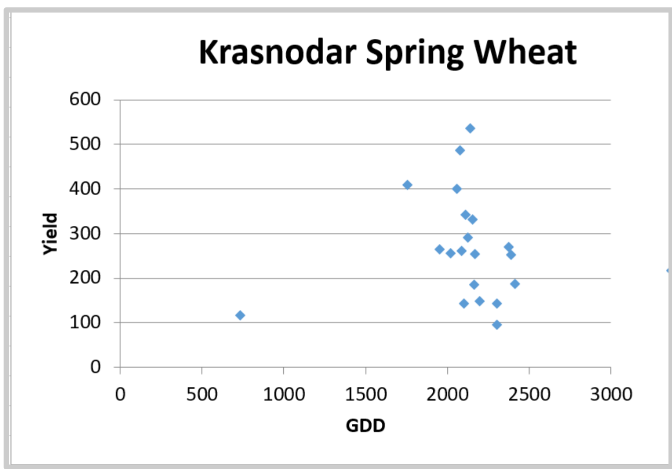


Figure 7. Krasnodar spring wheat GDD/yield before data pre-processing (1996-2015)

When collecting harvest and planting dates, we found that the data was extremely qualitative, described as “early May”, “mid-September”, etc. This is perfectly reasonable for a farmer who plants when the soil is deemed ready, but not sufficient for quantitative analysis. In order to accurately model these decisions, we further researched the favorable planting conditions for our four crops. Then, based on this information, we created an algorithm to search through the temperature database and select a planting day that meets these conditions.

Each crop has its respective GDD criteria to meet to reach its planting date (see Appendix B). However, GDD is not the only factor used. The typical growing season for our chosen crops covers a period of three months. Thus, our algorithm only selects a planting date that satisfies the GDD requirements within this time range. If this criteria was not met during this time period, the end of the time interval was selected as the planting date. This method of selecting planting dates creates a more accurate picture of actual GDD, giving us stronger models to predict crop growth. Harvest dates, on the other hand, remain relatively stable from year to year and do not require such attention.

We then realized that our collected yield data had varying amounts of total acreage per year contributing to this yield. An increased total acreage was resulting in an increased total yield for that year, i.e. causing a linear trend within the data (see Figure 8). Thus, to isolate the effects of GDDs on crop yield, we converted the raw yield data into yield per recorded acreage. The regression analysis then produced relatively strong results (see Figure 9 and Table 1). Thus, this relationship can be used to approximate how a predicted change in cumulative GDD in each region will affect the yield results for each crop, clearly demonstrating to the farmers their potential loss in yield. This is the first step in showcasing to them how the purchase of weather derivatives can compensate for this projected loss.

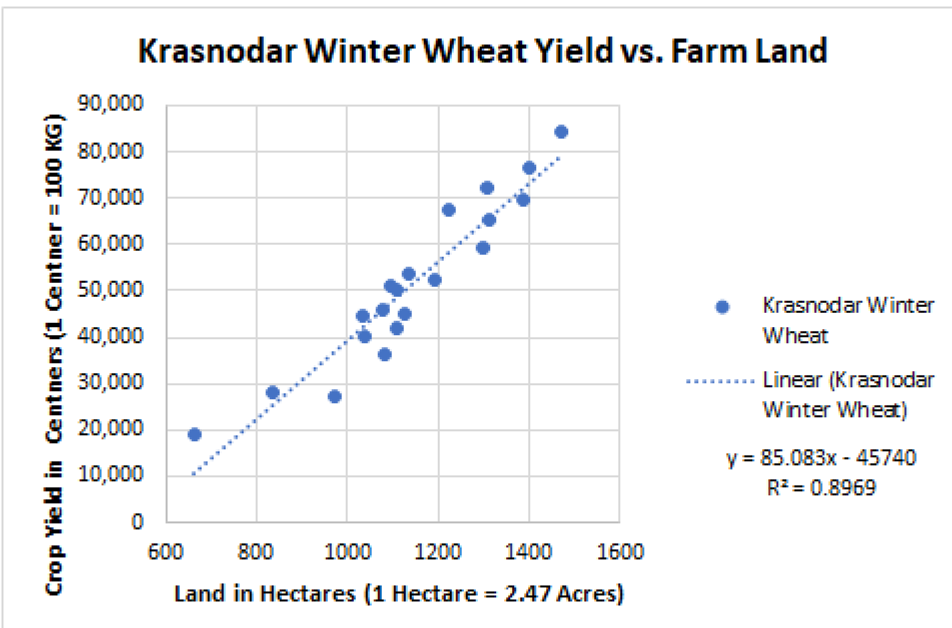


Figure 8. Trend between land acreage and crop yield for Krasnodar winter wheat (1996-2015)

Table 1. Yield Per Area vs Cumulative GDD Regression R^2 Values

Crop	Moscow	Krasnodar	Omsk
Corn	0.276	0.201	0.137
Potato	0.026	0.247	0.195
Spring Wheat	0.211	0.428	0.26
Winter Wheat	0.083	0.259	0.057

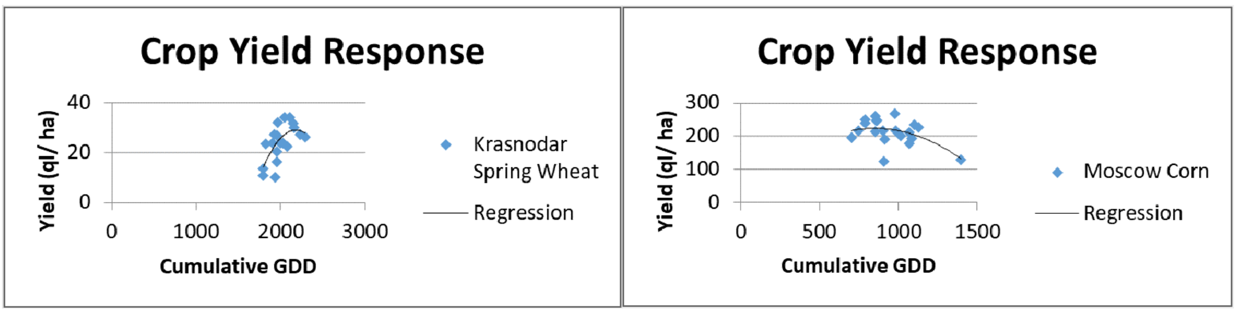


Figure 9. Krasnodar spring wheat and Moscow corn regression results (1996-2015)

4.2. Pricing Weather Derivatives

Following the formulas for pricing the weather derivatives, the farmer profits whenever the GDD hits one of two appropriate points (see Appendix A). However, it was not entirely clear how to adjust these pricing parameters so that farmers with a larger amount of farmland and a greater economic loss from poor weather conditions would be able to buy a weather derivative in order to collect a larger payout. In other words, we could not establish a relationship between farm size and premium. Therefore, we decided to add tick size as a user input for our simulation tool.

4.3. Creating Simulation Tool

The final deliverable of our project is an easy-to-use tool that compiles all of our work and demonstrates the effectiveness of weather derivatives to farmers, while also serving as a stepping stone for a practical implementation of this project. The tool performs situation-specific calculations based upon profile information provided by the user, e.g. crop type, location, farm size, and tick size (see Figure 10). Using this information as a basis for our parameters, the tool draws from a large Excel database to calculate the GDD/yield relationships, predicted GDDs and yields, the potential profit/loss of the farmer, and the price of the weather derivative. The farmer is then able to see his or her potential loss under various circumstances.

The program offers a large amount of flexibility in terms of upkeep, update potential, and data management. Data can easily be added into the Excel database for further processing as time passes and more weather and yield data is collected. The tool itself can easily be used by those with basic familiarity with Microsoft Office Products. The program's functionality demonstrates the potential effectiveness of utilizing weather derivatives for farming insurance and serves as a flexible and scalable tool that can generate further interest in the development of a weather derivatives program.

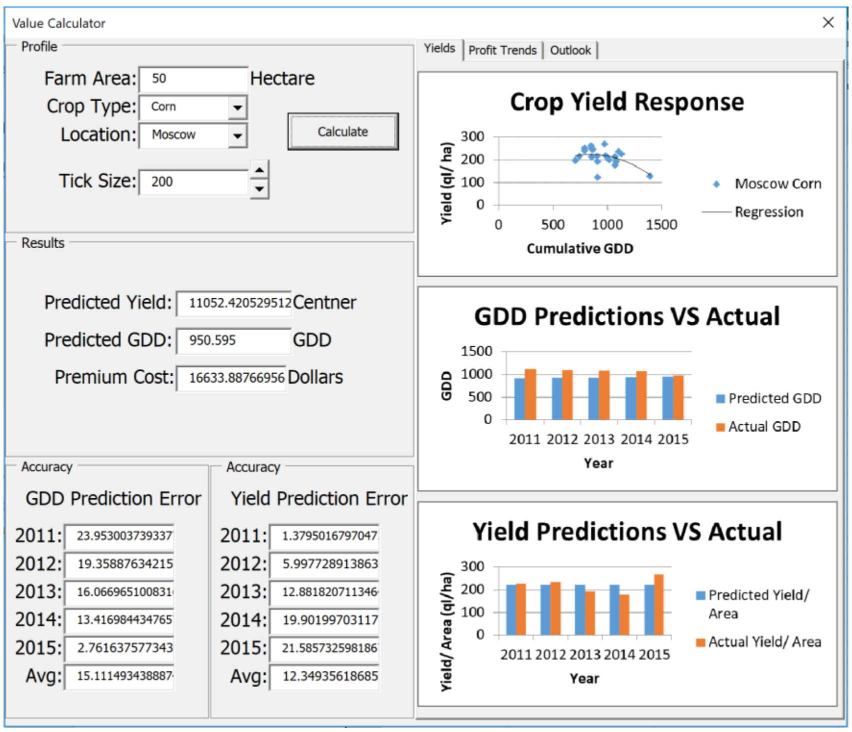


Figure 10. Tool interface

4.4. Testing Simulation Tool

In order to determine the accuracy of the simulation tool and whether weather derivatives are an effective hedging tool for farmers, we added testing code to the tool. This test code takes the last 5 years of the data base (the years 2011 through 2015), and treats them as future years. For each of these years, we predict the GDD, the crop yield, and produce a derivative option. The actual yield and GDD are then compared to what was predicted to determine accuracy, and the farmer's profit is compared to the derivative return to determine its effectiveness. As each past year is tested, its information is added back into the database for the next test calculation. The results show that as more data is added to the model, it becomes more accurate (see Figure 11 & 12). It also shows that with adjustment of the tick size, weather derivatives can help considerably to cover farmer's losses (see Figure 13).

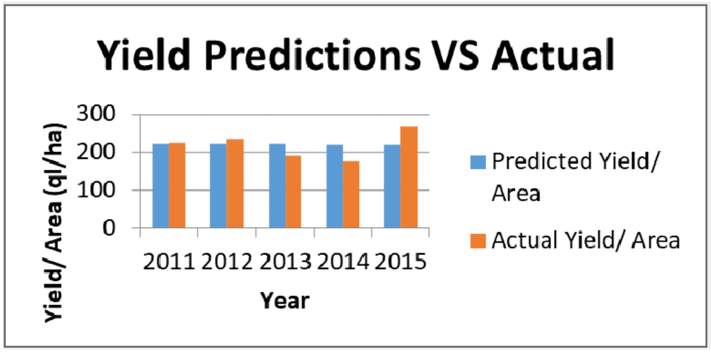


Figure 11. Accuracy of Predicted Yield Values

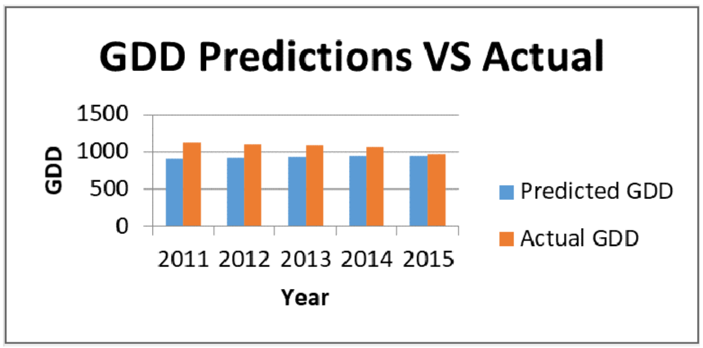


Figure 12. Accuracy of Predicted GDD Values

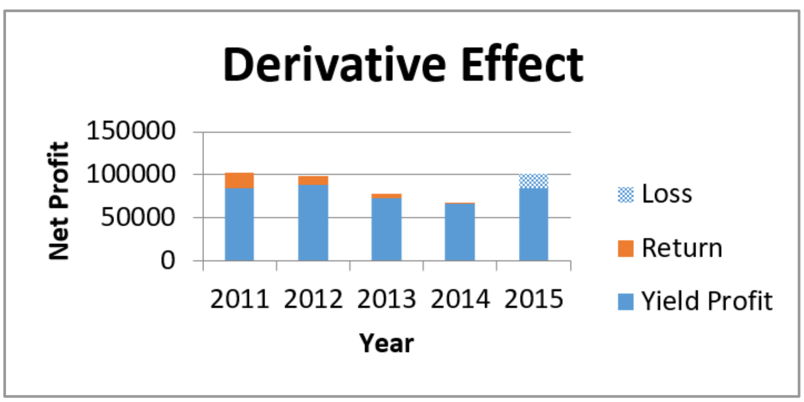


Figure 13. Profits with yield and weather derivative use

4.5. Advantages of the Simulation Tool

This simulation tool is effective in allowing other individuals to quickly visualize the potential benefits of utilizing weather derivatives as insurance. A farmer, or someone acting as a farmer for academic research, can input information that reflects their current economic position, and then gauge how effectively weather derivatives can mitigate their economic risks. In terms of development, it allows researchers to determine the efficiency of weather derivatives and adjust parameters as necessary when working towards a market implementation. For users, the tool's ability to easily convey the savings delivered by a derivative should generate popular interest in the product. The creation of this tool will hopefully spur the development of derivative-based insurance systems throughout Russia to further boost the agricultural sector development.

5. Conclusions and Recommendations

From our project work we have compiled a list of recommendations for the further development of this weather derivative tool. Ultimately, we recommend:

1. Testing the tool with real users
2. Promoting the tool amongst real users
3. Conducting laboratory experiments to determine the effect of precipitation on yield and create precipitation-based derivatives
4. Optimizing pricing parameters
5. Evaluating and applying other pricing techniques
6. Trading the weather derivatives on a local exchange trading system (LETS)

5.1. Testing with Real Users

In order to further confirm the effectiveness and reliability of this tool, it is imperative that actual farmers test it. These farmers would complete surveys and/or take part in focus groups to evaluate the ease of use of this tool and its accessibility. Additionally, these farmers can be used to judge the robustness of the constructed models. Users would record their actual crop loss versus their predicted loss and their actual compensation from the weather derivatives. The differences in the actual conditions and projected conditions would then be used to create more accurate models. Working with more relevant data and tracking the actual outcomes of these farmers' experiences would ultimately help to create a more beneficial tool in the future.

5.2. Promoting the Tool

Once the tool has been sufficiently tested, it is important that farmers are aware that this tool exists. As described above, many Canadian farmers did not even know that weather derivatives existed or did not how they could be used to help them (Van Camp, 2015). Thus, we recommend that our tool is promoted in a marketing campaign. This promotion would involve researching the methods of communication that are most valuable to farmers (e.g. publications in an agricultural magazine, workshops like those in the India system, word-of-mouth, etc.) and then promoting through these methods. The farmers will never be aware of how this tool can help them if they are never aware of the tool itself.

5.3. Testing the Effect of Precipitation and Constructing Precipitation-based Derivatives

One issue we encountered during the development of the GDD/yield model is that, even with the preprocessing of data, cumulative GDD is undoubtedly not the only factor that determines crop growth. As evident in Figure 9, some years experience a similar GDD but vastly different yields.

Precipitation also plays a key role in crop development. With global changes in climate and unstable precipitation patterns, it is especially important to factor in more than just temperature into our yield response model. Thus, we recommend conducting a future laboratory experiment that analyzes the effect precipitation has on overall yield for these crops. This experiment would expose crops to the same cumulative GDD, but change the amount of water each plant receives and document each crop's growth rates. A similar experiment should also be conducted that maintains constant water levels and varies the GDDs.

Comparing the results of each of these tests would reveal which factor is more critical for the growth of different crops. A similar precipitation/yield model could be constructed so that farmers can visualize how future rainfall predictions will affect their crops. Weather derivatives based on a cumulative rainfall index could also be priced if necessary. This will allow farmers to pick between a GDD or a precipitation derivative, depending on whichever is more unpredictable and/or influential in their region.

5.4. Optimizing Pricing Parameters

The goal of this weather derivatives system is to compensate farmers for their agricultural losses due to unfavorable weather conditions. The weather derivative makes a payment to the farmer under certain temperature conditions, but further research must be done to optimize the pricing parameters to ensure that farmers' premiums are affordable to the farmer and that these payouts provide substantial compensations.

For example, the strike values of the weather derivative are currently set at 0.2 standard deviations away from the mean cumulative GDD values. By setting the strike values at a larger standard deviation away, we could decrease the cost of the premium, but also decrease the likelihood of receiving payout from the derivative. Thus, a balance must be found between the initial premium cost and meaningful levels of compensation when the weather conditions are not favorable.

5.5. Evaluating Other Pricing Methods

Finding the best methods to price weather derivatives is an open research problem. As stated before, we selected the historical burn analysis and because the data needed for processing was accessible and the technique proved to be effective in previous research papers. The mathematical concepts presented were also easy to grasp and implement by our team in Excel within a limited timeframe.

Currently more accurate methods of pricing exist, even if they were not feasible for our team to calculate. For example, Taylor and Buizza (2006) use ensemble forecasting to create their weather prediction model with data provided by the European Centre for Medium-range Weather Forecasts (ECMWF), a source which we did not have access to. With higher-fidelity forecasting models, more accurate derivative pricing will ensue and more protection will be provided to the farmers. Because weather prediction continues to be uncertain, we recommend a more comprehensive comparison of weather derivative pricing that encompasses techniques outside of those presented here. This will either affirm the accuracy of our methods or provide even more accurate pricing methods.

5.6. Trading Weather Derivatives

Most weather derivatives are currently traded on the market using over-the-counter (OTC) transactions, meaning they are not traded on formal exchange systems like NASDAQ or Dow Jones but privately negotiated between two parties (Investopedia, n.d.). We did not pursue research into bringing the derivatives to a real-world market due to lack of time for the project. Eventually this weather derivatives system should be brought out of academia and into the real-world. We recommend further research into trading derivatives on an online local exchange trading system (LETS) so that contracts can be easily bought and sold all around the world. Additionally, all derivative transactions could take place utilizing Blockchain technology, eliminating the need for clearing houses as well as third-party security issues. This would also decrease costs to users and increase their profits (Iansiti & Lahkani, 2017).

5.7. Conclusion

With global climate change altering weather patterns, Russian farmers are in need of protection from everyday weather events that will negatively affect their crop yields. This type of protection is not currently offered through traditional methods of agricultural insurance or government subsidies and furthermore, Russian farmers have a lack of faith in these products. Through the use of weather derivatives, these farmers should be able to hedge these risks at an affordable premium price. To build a weather derivative simulation tool, our team constructed a model that demonstrates the relationship between cumulative GDD within a growing season and crop yield for corn, potatoes, and wheat in the Moscow, Krasnodar, and Omsk regions. We were then able to price weather derivatives, displaying these results and models on the Excel simulation tool. This tool is able to demonstrate how predicted GDDs will affect farmers' yields and how they can protect themselves from potential economic loss and thus boost popular interest in a weather derivatives system in Russia.

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Appendices

Appendix A. Relevant Equations

A **Growing Degree Day (GDD)** is defined as,

$$GDD_{i,n,c} := \frac{T_{max,i,n}+T_{min,i,n}}{2} - T_c,$$

where $T_{max,i,n}$ and $T_{min,i,n}$ are the maximum and minimum recorded temperatures, respectively, for day, i and year, n; and T_c is the base temperature for crop, c.

Cumulative GDD is defined as,

$$\sum_{i=s}^{q} GDD_{i,n,c}\ ,$$

where s and q are the start and end dates of the growing season, respectively.

The **expected payout** for a weather derivative with low GDD or high GDD is defined as,

$$E_{p,LOW} = D\sigma[\phi(n) + n\Phi(n)]$$

or $$E_{p,HIGH} = D\sigma[\phi(m) - m + m\Phi(m)],$$

where D is the tick size (dollar value per unit of GDD), μ is the mean value of GDD's, σ is the standard deviation of the GDD's, ϕ is the PDF of the standard normal distribution, Φ is the CDF of the standard normal distribution, and

$$n := \frac{K_1-\mu}{\sigma},$$
$$m := \frac{K_2-\mu}{\sigma},$$

where K_1 is the strike value for the low GDD value, and K_2 is the strike value for the high GDD value (see Sun and van Kooten (2015) for derivation). The dollar is used as the choice of currency in the tick size because of its historic stability (Glenn, 2017). Thus, the price or payout of an option will not fluctuate due to inflation.

The **price (premium)** of the option is defined as,

$$c = e^{-r(u-v)}E_p,$$

where c is the premium that hedgers pay for the contract, r is a risk-free periodic market interest rate, v is the date that contract was issued/purchased, and u is the date the contract was claimed/expiration date. E_p is the expected payoff based on predicted or historic mean value of temperatures (see Sun and van Kooten for the derivation).

The **actual payout** is defined as,

$$p(x)_{farmer} = \begin{cases} D(K_1 - x), & x \le K_1 \\ 0, & K_1 < x < K_2 \\ D(x - K_2), & x \ge K_2 \end{cases},$$

where x is the realized cumulative GDD.

In a **historic burn analysis**, the expected payout is set equal to the average historical weather conditions. In the case of GDD it is defined as,

$$\mu := \frac{\sum_{j=1}^{n} \sum_{i=s}^{q} GDD_{i,j,c}}{n}.$$

In the derivative tool, the interest rate, contract length, risk loading factor, and m and n values were fixed (see Table 2).

Table 2. Derivative Parameters

Derivatrive Variable	Value
Tick Size	200
mean weather	950.595
dev. Weather	157.9873491
Put Strike Val	1280
Call Strike Val	1310
interest rate	0.08
Contract Length	0.75
Risk Loading Factor	0.25
m	0.2
n	-0.2

Appendix B. Crop Planting and Harvest Dates

Table 3. Potato, Corn, and Wheat Planting/Harvest Dates

Crop	***Planting Date***	***Harvest Date***
Potato	- Plant about 2 to 4 weeks before last frost date	- Early October
Corn	- late May or early June - GDD > 0 - Sum of three weeks GDD > 90	- 4 -11 days before last frost date
Spring Wheat	- April - May - GDD > -1.5 - After 10 days, GDD reach average 5.6	- Moscow & Krasnodar: August 1 - Omsk: August: 25
Winter Wheat	- February - Average GDD ≥-5 for two weeks	- July - August

APK-Inform (2004), Cereals of Russia (n.d.), Growing Guide (2006), Sfgate (n.d.) & Veggieharvest (n.d.)

Table 4. Moscow, Krasnodar, and Omsk frost dates

Region	***Last Frost date***	***First Frost Date***
Moscow	May 1 - May 10	Oct. 1 - Oct. 10
Krasnodar	Mar. 21 - Mar. 31	Oct. 21 - Oct. 31
Omsk	May 1 - May 10	Sep. 11 - Sep. 20

Interactive Russia First Frost Date Map (2016) & Interactive Russia Last Frost Date Map (2016)

Appendix C. Record of Project Development

Figure 14. Team photo (from left to right: Marshall, Anastasia, Vladislav S., Congshan, Stanislav, Alyona, Vladislav T., Caroline, Eric)

Figure 15. Vladislav T. and Caroline presenting on the pricing of weather derivatives

Figure 16. Anastasia and Eric presenting on educating farmers and the simulation tool

Figure 17. Taking a break from the project to enjoy Stanislav's magic tricks

Appendix D: Simulation Tool VBA Code

```
'Created By: Eric Carkin: ewcarkin@wpi.edu

'10/9/2017

'Code for weather derivative examination

'Please note, some calculations are done on spread sheet, and this code will not work

'without its corresponding workbook


Option Explicit

Dim Crop_Type As String

Dim Crop_Val As Double

Dim Crop_Column As String

Dim Season_SD() As String

Dim Season_ED() As String

Dim Num_Years(1 To 30) As Integer

Dim Sheet_Name As String

Dim Data_StartYr As Integer

Dim Projected_GDD As Double

Dim Technique As Integer

Dim Temp_Floor As Double

Dim Days As Integer

Dim Date_Track As Integer

Dim Equation_Text As String

Dim R_Square As String


Dim D As Double 'tick size

Dim U As Double 'mean value of weather index

Dim DEV As Double 'standard deviation of weather index

Dim K1 As Double 'Strike price for put option

Dim K2 As Double 'Stike price for call option

Dim R As Double 'risk-free periodic market interest rate

Dim RL As Double 'risk loading factor

Dim Contract_Range As Double 'time period of contract
```

```
Dim Put_Val As Double 'payoff for put option
Dim Call_Val As Double 'payoff for call option
Dim m As Double 'param
Dim n As Double 'param
Dim Num_DataYr As Integer 'number of years in data base

Dim Call_Divisions(1 To 5) As Double
Dim Put_Divisions(1 To 5) As Double

'calc v2
Dim Start_Month As Integer
Dim Init_GDD As Double
Dim Avg_Time As Double
Dim Min_Avg_Value As Double

Dim GDD2012 As Double
Dim GDD2013 As Double
Dim GDD2014 As Double
Dim GDD2015 As Double
Dim GDD2016 As Double
Dim GDD2017 As Double

Dim Historic_GDD As Double

Dim Wheat_Val As Double
Dim Corn_Val As Double
Dim Potato_Val As Double

Dim Crop_Region As String
Dim Crop_Day As Integer
Dim Crop_Month As Integer
Dim Temp_EndCell As Integer
```

```
Dim Letter_Array(1 To 26) As String

Dim Month_Lengths(1 To 26) As Integer 'holds number of days to add to begining of year(felxability to change data/ leap years)


Function Calc_PDF(Distribution As Double) As Double

'PDF of the standard nomral distribution

Calc_PDF = (1 / Sqr(2 * WorksheetFunction.Pi)) * Exp((-1) * (Distribution ^ 2) / 2)

End Function


Function Calc_CDF(Distribution As Double) As Double

'CDF of the standard normal dsitributiom

Calc_CDF = 0.5 * (WorksheetFunction.Erf(Distribution / Sqr(2)) + 1)

End Function


Function Burn_analysis(Year_Count As Integer)

'Averages past GDDs to predict futureGDD aka the mean

Dim Count As Integer

Dim Avg_Count As Double

Projected_GDD = 0

Avg_Count = 0

For Count = 3 To (Year_Count + 3) 'look at yearly GDDs, avg the valid ones togther

If (Worksheets("Specs").Range("I" & CStr(Count)) <> 0) And Not IsEmpty(Worksheets("Specs").Range("I" & CStr(Count))) Then

Projected_GDD = Projected_GDD + Worksheets("Specs").Range("I" & CStr(Count))

Avg_Count = Avg_Count + 1

End If

Next Count

If (Avg_Count = 0) Then

MsgBox "Error! No GDD Found"

Else

Projected_GDD = Projected_GDD / Avg_Count

End If

Worksheets("Specs").Range("F4") = Projected_GDD

U = Projected_GDD
```

```
End Function

Sub FindDeviation() 'caclulates deviation of hisoric data
Dim Count As Integer
Dim Sum As Double
Dim Divide As Double
Dim Mean As Double
Mean = Worksheets("Specs").Range("F4") 'aka gdd prediction
Sum = 0
Divide = 0
For Count = 1 To 20
If Not IsEmpty(Worksheets("Specs").Range("I" & CStr(2 + Count))) Then
Sum = Sum + (((Worksheets("Specs").Range("I" & CStr(2 + Count))) - Mean) ^ 2)
Divide = Divide + 1
End If
Next Count
Worksheets("Specs").Range("F5") = Sqr(Sum / Divide)
DEV = Worksheets("Specs").Range("F5") 'save to spread sheet
End Sub
Function Update_Val(Num_Years As Integer) 'reset calcualtions, redo with argument number of years (for historic check)
Call Burn_analysis(Num_Years)
Call FindDeviation
Call Find_Put_Strike
Call Find_Call_Strike
End Function

Sub Find_Put_Strike()
'calculates put strike price
K1 = (DEV * n) + U
End Sub

Sub Find_Call_Strike()
```

```
'caclulates call strike price

K2 = (DEV * m) + U

End Sub


Function Premium_Calc() As Double 'calculates premium

Dim Ep As Double

Ep = D * DEV * (Calc_PDF(m) - m + (m * Calc_CDF(m)))

Premium_Calc = (1 + RL) * Exp(-R * (Contract_Range)) * Ep

End Function


Sub Reset()

Dim Count As Integer 'clears spread sheets values (note: may not clear some values)

For Count = 3 To 28

Worksheets("Specs").Range("I" & CStr(Count)) = Null

Worksheets("Specs").Range("J" & CStr(Count)) = Null

Next Count


For Count = 32 To 36

Worksheets("Specs").Range("F" & CStr(Count)) = Null

Worksheets("Specs").Range("G" & CStr(Count)) = Null

Worksheets("Specs").Range("I" & CStr(Count)) = Null

Next Count


End Sub


Private Sub Calculate_Click() 'performs squence of calculations

Call Reset

Date_Track = 0

Days = 0

Dim cht As Chart

Dim rng As Range

Dim imageName As String
```

```
Dim Count As Integer
Dim Count1 As Integer
Dim completed_range As Boolean
Dim processed_days As Integer
Dim processed_months As Integer
Dim start_cell As String
Dim end_cell As String
Dim in_range As Boolean
Dim Days_Count As Integer
Dim Years_Count As Integer
Dim Cold_Snap As Boolean
Cold_Snap = False


'clear yield and GDD vals
For Count = 1 To Num_DataYr
Worksheets("Specs").Range("J" & CStr(Count + 2)) = Null
Worksheets("Specs").Range("I" & CStr(Count + 2)) = Null
Next Count

If (Crop_Type <> " ") And (AreaInput.value <> 0) Then 'if all required data is entered perform calculations

For Count = 3 To 21 'search for crop type within the specified crop types
If Crop_Type = Worksheets("Specs").Range("B" & CStr(Count)) Then 'if we found it, load information
Crop_Val = Worksheets("Specs").Range("C" & CStr(Count))  'rubles per ton
Season_SD = Split(Worksheets("Specs").Range("D" & CStr(Count)), ",")
End If
Next Count
Sheet_Name = Location.value & " Historic GDD" 'define which sheet contains the relevant information

For Count = 27 To 45 'Search for crop
If Crop_Type = Worksheets(Sheet_Name).Range("BA" & CStr(Count)) Then
```

```
Start_Month = Worksheets(Sheet_Name).Range("BB" & CStr(Count))

Init_GDD = Worksheets(Sheet_Name).Range("BC" & CStr(Count))

Avg_Time = Worksheets(Sheet_Name).Range("BD" & CStr(Count))

Min_Avg_Value = Worksheets(Sheet_Name).Range("BE" & CStr(Count))

Season_ED = Split(Worksheets(Sheet_Name).Range("BF" & CStr(Count)), ",")

Temp_Floor = Worksheets(Sheet_Name).Range("BG" & CStr(Count))

Technique = Worksheets(Sheet_Name).Range("BH" & CStr(Count))

End If

Next Count




in_range = False 'flag for tracking where we are in data

completed_range = False 'flag for tracking where we are in data

Historic_GDD = 0 'avg gdd for given crop


For Count = 1 To 18 'on the relevant sheet, look for which column has the crop GDD we are looking for

If Not IsEmpty(Worksheets(Sheet_Name).Range("A" & Letter_Array(Count) & "3")) Then

If (InStr(1, Crop_Type, Worksheets(Sheet_Name).Range("A" & Letter_Array(Count) & "3")) > 0) Then

Crop_Column = ("A" & Letter_Array(Count))

'MsgBox Crop_Column

End If

End If

Next Count


Call FindYears 'define where the start and end of years are in the data


Count = 0

processed_days = 4 'cell location of days

processed_months = 0 'number of months we have counted


Dim Avg_Found As Boolean
```

```
Dim Averaging As Double
Averaging = 0
Avg_Found = False
For Years_Count = 1 To Num_DataYr 'progress through 20 years of data
processed_months = 0 'reset months
Historic_GDD = 0 'reset GDD
If Num_Years(Years_Count + 1) - Num_Years(Years_Count) > 360 Then 'if there is a complete year of data, continue with progression
Count = Count + 1

For Days_Count = 0 To (Num_Years(Years_Count + 1) - Num_Years(Years_Count)) 'for all days in the year

If (Worksheets(Sheet_Name).Range("D" & CStr(Num_Years(Years_Count) + Days_Count)) = 1) Then 'if the day is a one, start of new
month
processed_months = processed_months + 1 'increase number of months
End If

'If we are in what is considered a valid range for planting the crop in question, or are in the growing season,
'and is not pass harvest date, and the GDD satisifes crop req
If Not IsEmpty(Worksheets(Sheet_Name).Range(Crop_Column & CStr(Num_Years(Years_Count) + Days_Count))) Then
If (Worksheets(Sheet_Name).Range(Crop_Column & CStr(Num_Years(Years_Count) + Days_Count)) >= Init_GDD) And Not Avg_Found
And (processed_months < Season_ED(1)) And processed_months >= (Start_Month - 1) Then

Select Case Technique

Case 1 'corn/ potato- take a number of days (defined by crop type) and average the GDD over that range
Averaging = 0
For Count = (Num_Years(Years_Count) + Days_Count) To (Num_Years(Years_Count) + Days_Count + Avg_Time)
Averaging = Averaging + Worksheets(Sheet_Name).Range(Crop_Column & CStr(Count)) 'start averaging data
Next Count
Averaging = Averaging / Avg_Time
If Averaging >= Min_Avg_Value Then 'if avg satisfies crop req, allow for GDD calculation to start
Avg_Found = True
```

```
Days = (Num_Years(Years_Count) + Days_Count)
Call Find_Season 'indicate what start days are being used- (Developer Use)
End If

Case 2 'winter wheat look over number of days decided by crop type, if temp drops below certain cut off, search for new range, other
wise find GDD
Avg_Found = True
For Count = (Num_Years(Years_Count) + Days_Count) To (Num_Years(Years_Count) + Days_Count + Avg_Time)
If Worksheets(Sheet_Name).Range("E" & CStr(Count)) < Temp_Floor Then
Avg_Found = False
End If
Next Count
If Avg_Found Then
Days = (Num_Years(Years_Count) + Days_Count)
Call Find_Season 'indicate what start days are being used (Developer use)
End If

Case 3 'spring wheat
For Count = (Num_Years(Years_Count) + Days_Count + 10) To (Num_Years(Years_Count) + Days_Count + Avg_Time + 10)
Averaging = Averaging + Worksheets(Sheet_Name).Range(Crop_Column & CStr(Count)) 'start averaging data
Next Count
Averaging = Averaging / Avg_Time
If Averaging >= Min_Avg_Value Then
Avg_Found = True
End If
If Avg_Found Then
Days = (Num_Years(Years_Count) + Days_Count)
Call Find_Season
End If

End Select
End If
```

```
If processed_months > (Start_Month + 1) And Not Avg_Found And (processed_months < Season_ED(1)) Then
Avg_Found = True
Days = (Num_Years(Years_Count) + Days_Count)
Call Find_Season
End If

If (Avg_Found) Then
Historic_GDD = Historic_GDD + Worksheets(Sheet_Name).Range(Crop_Column & CStr(Num_Years(Years_Count) + Days_Count)) 'add gdd
of that day
End If

If (processed_months = Val(Season_ED(1)) And (Worksheets(Sheet_Name).Range("D" & CStr(Num_Years(Years_Count) + Days_Count)) =
Val(Season_ED(0)))) Then
Avg_Found = False
End If

'End If
End If
Next Days_Count
End If
Worksheets("Specs").Range("I" & CStr(Data_StartYr - 1994 + Years_Count)) = Historic_GDD 'fill chart with GDD for each historic year for
crop
Historic_GDD = 0
If (Years_Count = 3 And Crop_Region = "Krasnodar") Then
Worksheets("Specs").Range("I" & CStr(Data_StartYr - 1994 + Years_Count)) = Null
End If
Next Years_Count

For Count = 1 To 18
If (InStr(1, Worksheets(Sheet_Name).Range("B" & Letter_Array(Count) & "1"), Crop_Type) > 0) Then 'look for yield data, when we find
the correct set, fill in the data on spec page
 For Count1 = 1 To 20
```

```
 Worksheets("Specs").Range("J" & CStr(Count1 + 2)) = Worksheets(Sheet_Name).Range("B" & Letter_Array(Count) & CStr(Count1 + 1))
Next Count1
End If
Next Count



start_cell = ("I" & CStr(Data_StartYr - 1993) & ":J23") 'define start of data for chart
Set rng = Worksheets("Specs").Range(start_cell)
Set cht = Worksheets("RSquare").Shapes.AddChart(xlXYScatter).Chart 'create chart

'create chart
Worksheets("RSquare").Activate
Dim trend As Trendline
With cht
  .SetSourceData Source:=rng
  .ChartType = xlXYScatter
  .HasTitle = True
  .ChartTitle.Text = "Crop Yield Response"
  .Axes(xlCategory).HasTitle = True
  .Axes(xlCategory).AxisTitle.Text = "Cumulative GDD"
  .Axes(xlValue).HasTitle = True
  .Axes(xlValue).AxisTitle.Text = "Yield (ql/ ha)"
  .SeriesCollection(1).Name = Crop_Region & " " & Crop_Type

  'capture r^2 and trendline equation
  Set trend = .SeriesCollection(1).Trendlines.Add(xlPolynomial)
  trend.Name = "Regression"
  trend.DisplayEquation = True
  trend.DisplayRSquared = False
  trend.DataLabel.NumberFormat = "0.0000E+00"
  trend.DataLabel.Select
```

```
    Equation_Text = Selection.Characters.Text
    trend.DisplayEquation = False
    trend.DisplayRSquared = True
    trend.DataLabel.Select
    R_Square = Selection.Characters.Text
    trend.DisplayRSquared = False
    .Axes(xlValue).MinimumScale = 0
End With

Worksheets("RSquare").ChartObjects.Height = Temperature.Height
Worksheets("RSquare").ChartObjects.Width = Temperature.Width
imageName = Application.DefaultFilePath & Application.PathSeparator & "TempChart.gif"
cht.Export Filename:=imageName 'make chart an image
'Worksheets("Calculations").ChartObjects(1).Delete 'delete chart on the excel page
Application.ScreenUpdating = True
ValueCalculator.Temperature.Picture = LoadPicture(imageName) 'show chart on interface

Worksheets("Specs").Activate

Update_Val (20) 'finds future gdd, and deviation

Predicted_Yield.value = Predict_YieldEq(Projected_GDD) * AreaInput.value 'predict yield from yield response and projected GDD
Predicted_GDD.value = Projected_GDD 'show predicted GDD

Call Weather_Test
Call Calc_Financial
Else
MsgBox "Please Enter all Required Information"
End If
End Sub

Function Predict_YieldEq(x As Double) As Double ' finds yield response equation and evals
```

```
    Dim Sub_Eq As String
    Sub_Eq = Equation_Text
    Sub_Eq = Replace(Sub_Eq, "y =", "")
    Sub_Eq = Replace(Sub_Eq, "x2", "x^2")
    Sub_Eq = Replace(Sub_Eq, "x", " * " & x & " ")
    Predict_YieldEq = CDbl(Evaluate(Sub_Eq))
End Function


Sub Find_Season() 'determines what month of data we are looking at based upon the progression day count, shows it on calculation page for operation check
Days = Days - 3 '3 days are added to count to get past headers
While (Days > 366) 'data base uses 366 days to account for leap year (if not a leap year the extra day has no data)
Days = Days - 366 'subtract 366 days until we are dealing with a span of days in one year
Wend
Date_Track = Date_Track + 1
If (0 < Days And Days <= 31) Then
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Jan"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (31 < Days And Days <= 60) Then
Days = Days - 31
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Feb"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (60 < Days And Days <= 91) Then
Days = Days - 60
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Mar"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (91 < Days And Days <= 121) Then
Days = Days - 91
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "April"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (121 < Days And Days <= 152) Then
```

```
Days = Days - 121
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "May"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (152 < Days And Days <= 182) Then
Days = Days - 152
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "June"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (182 < Days And Days <= 213) Then
Days = Days - 182
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "July"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (216 < Days And Days <= 244) Then
Days = Days - 216
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Aug"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (244 < Days And Days <= 274) Then
Days = Days - 244
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Sep"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (274 < Days And Days <= 305) Then
Days = Days - 274
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Oct"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (305 < Days And Days <= 335) Then
Days = Days - 305
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Nov"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
ElseIf (335 < Days And Days <= 366) Then
Days = Days - 335
Worksheets("Calculations").Range("A" & CStr(Date_Track)) = "Dec"
Worksheets("Calculations").Range("B" & CStr(Date_Track)) = Days
End If
```

```
End Sub

Sub FindYears() 'records locations of the start/ ending of years of data
Dim end_data As Boolean
Dim Year_Count As Integer
Dim processed_days As Integer
Dim processed_months As Integer
end_data = False
Year_Count = 1
processed_days = 4 'days dont start until 4th row
processed_months = 0
While (Not end_data) 'we potentially do not know length of data, so go until we find an end indicator
If (IsEmpty(Worksheets(Sheet_Name).Range("D" & CStr(processed_days)))) Then 'if the cell is empty, the end of data has been reached
end_data = True
Num_Years(Year_Count) = (processed_days - 1) 'the last entry of the years_num array is the last counted day
End If

If (Worksheets(Sheet_Name).Range("D" & CStr(processed_days)) = 1) Then 'if the data is a 1, its the start of a new month
If (processed_months = 0) Then 'if processed months = 0, indicator we have started a new year
Num_Years(Year_Count) = (processed_days) 'Num_Years holds the cell location of the start/ end of each year, load the start location of
new year
Year_Count = Year_Count + 1 '
End If
processed_months = processed_months + 1 'increase the num of months
If (processed_months = 12) Then 'if we have 12 months, set to zero so next month will start a new year
processed_months = 0
End If
End If

processed_days = processed_days + 1 'increase the day count
Wend
End Sub
```

```
Private Sub CropChoice_Change()
'change type of crop we are using
Crop_Type = CropChoice.value
End Sub

Private Sub Location_Change()
'selects the region we are dealing with
Crop_Region = Location.value
End Sub

Sub Weather_Test() 'performs calculations to show accuracy of tool over last 5 years
Dim Year As Integer
Dim Historical As Integer
Dim Average As Double
Dim Divider As Double
Dim GDD_cht As Chart
Dim Yield_cht As Chart
Dim Pre_GDD As Range
Dim Act_GDD As Range
Dim Pre_Yield As Range
Dim Act_Yield As Range
Dim Graph_Years As Range
Dim imageName As String
Dim value As Double


For Year = 1 To 5 '5 yrs of historical data
   Average = 0
```

```
    Divider = 0 ' go through the past data up until the year we are predicting
    For Historical = 1 To (14 + Year)
        If Not IsEmpty(Worksheets("Specs").Range("I" & CStr(2 + Historical))) Then 'add GDD if present, keep track of additions to do an avg
later
        Average = Average + Worksheets("Specs").Range("I" & CStr(2 + Historical))
        Divider = Divider + 1
        End If
    Next Historical
    If Average <> 0 Then 'if there was data to add
    Average = Average / Divider 'find average
    Worksheets("Specs").Range("F" & CStr(Year + 31)) = Average 'avg is the prediction for the next year
    Else
    MsgBox "Error, No Valid GDD" 'no GDD present, alert user
    End If
    If Not IsEmpty(Worksheets("Specs").Range("I" & CStr(Year + 17))) Then
    Worksheets("Specs").Range("G" & CStr(Year + 31)) = Worksheets("Specs").Range("I" & CStr(Year + 17)) 'put actual gdd in table
    End If
Next Year

For Year = 1 To 5
    If Not IsEmpty(Worksheets("Specs").Range("F" & CStr(Year + 31))) Then
    value = Worksheets("Specs").Range("F" & CStr(Year + 31))
    Worksheets("Specs").Range("I" & CStr(Year + 31)) = Predict_YieldEq(value) 'if a prediction was made, determine what the predicted
yield is
    Else
    MsgBox "Missing Data"
    End If
Next Year

'set up graph parameters
Set Pre_GDD = Worksheets("Specs").Range("F32:F36")
Set Act_GDD = Worksheets("Specs").Range("G32:G36")
```

```
Set Pre_Yield = Worksheets("Specs").Range("I32:I36")
Set Act_Yield = Worksheets("Specs").Range("J32:J36")
Set Graph_Years = Worksheets("Specs").Range("E32:E36")
Set GDD_cht = Worksheets("Calculations").Shapes.AddChart(xlColumnClustered).Chart 'create chart
Set Yield_cht = Worksheets("Calculations").Shapes.AddChart(xlColumnClustered).Chart 'create chart
'create chart
Worksheets("Calculations").Activate
With GDD_cht
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Predicted GDD"
    .SeriesCollection(2).Name = "Actual GDD"
    .SeriesCollection(1).Values = Pre_GDD
    .SeriesCollection(1).XValues = Graph_Years
    .SeriesCollection(2).Values = Act_GDD
    .SeriesCollection(2).XValues = Graph_Years
    .ChartType = xlColumnClustered
    .HasTitle = True
    .ChartTitle.Text = "GDD Predictions VS Actual"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "Year"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "GDD"
End With

Worksheets("Calculations").ChartObjects.Height = GDD.Height
Worksheets("Calculations").ChartObjects.Width = GDD.Width
imageName = Application.DefaultFilePath & Application.PathSeparator & "GDDChart.gif"
GDD_cht.Export Filename:=imageName 'make chart an image
Worksheets("Calculations").ChartObjects(1).Delete 'delete chart on the excel page
Application.ScreenUpdating = True
ValueCalculator.GDD.Picture = LoadPicture(imageName) 'show chart on interface
```

```
With Yield_cht
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Predicted Yield/ Area"
    .SeriesCollection(2).Name = "Actual Yield/ Area"
    .SeriesCollection(1).Values = Pre_Yield
    .SeriesCollection(1).XValues = Graph_Years
    .SeriesCollection(2).Values = Act_Yield
    .SeriesCollection(2).XValues = Graph_Years
    .ChartType = xlColumnClustered
    .HasTitle = True
    .ChartTitle.Text = "Yield Predictions VS Actual"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "Year"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "Yield/ Area (ql/ha)"
End With

Worksheets("Calculations").ChartObjects.Height = Yield.Height
Worksheets("Calculations").ChartObjects.Width = Yield.Width
imageName = Application.DefaultFilePath & Application.PathSeparator & "YieldChart.gif"
Yield_cht.Export Filename:=imageName 'make chart an image
Worksheets("Calculations").ChartObjects(1).Delete 'delete chart on the excel page
Application.ScreenUpdating = True
ValueCalculator.Yield.Picture = LoadPicture(imageName) 'show chart on interface

Worksheets("Specs").Activate
Call Show_Accuracy
End Sub
```

```
Function Derivative_Return(Act_GDD As Double) As Double
Call Find_Call_Strike
Call Find_Put_Strike
If (Act_GDD >= K2) Then
Derivative_Return = D * (Act_GDD - K2)
ElseIf (K1 >= Act_GDD) Then
Derivative_Return = D * (K1 - Act_GDD)
Else
Derivative_Return = 0
End If
End Function

Sub Calc_Financial() 'calculates and shows the premium for each predicted yr
Dim Call_Cht As Chart
Dim Put_Cht As Chart
Dim Count As Integer
Dim Returns As Range
Dim X_Axis As Range
Dim imageName As String
Dim Normal_Return As Range
Dim Yield_Loss As Range
Dim Outlook As Chart
Dim GDD_Input As Range
Dim Derivative_Output As Range
Dim Yield_Profit As Range
Dim ProfitMargins_Cht As Chart
Dim Crop_Relation As Range
Dim Outlook_2011 As Chart
Dim Outlook_2012 As Chart
Dim Outlook_2013 As Chart
Dim Outlook_2014 As Chart
Dim Outlook_2015 As Chart
```

```
Dim Loss_Margins As Range

Set Outlook_2011 = Worksheets("OutlookGraphs").Shapes.AddChart(xlLine).Chart
Set Outlook_2012 = Worksheets("OutlookGraphs").Shapes.AddChart(xlLine).Chart
Set Outlook_2013 = Worksheets("OutlookGraphs").Shapes.AddChart(xlLine).Chart
Set Outlook_2014 = Worksheets("OutlookGraphs").Shapes.AddChart(xlLine).Chart
Set Outlook_2015 = Worksheets("OutlookGraphs").Shapes.AddChart(xlLine).Chart


Update_Val (15) 'find premium costs for 15 yrs of data
Worksheets("Specs").Range("N3") = Premium_Calc()
'Call Return_Data(Premium2011.value, 1)
Call Return_Data(Premium_Calc(), 1)
Set GDD_Input = Worksheets("OutlookGraphs").Range("A1:A23")
Set Derivative_Output = Worksheets("OutlookGraphs").Range("B1:B23")
Set Crop_Relation = Worksheets("OutlookGraphs").Range("C1:C23")

With Outlook_2011 'plot return graph
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Return"
    .SeriesCollection(1).Values = Derivative_Output
    .SeriesCollection(1).XValues = GDD_Input
    .SeriesCollection(2).Name = "Crop Growth"
    .SeriesCollection(2).Values = Crop_Relation
    .SeriesCollection(2).XValues = GDD_Input
    .ChartType = xlLine
    .HasTitle = True
    .ChartTitle.Text = "2011 Derivative Return"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "GDD"
    .Axes(xlValue).HasTitle = True
```

```
    .Axes(xlValue).AxisTitle.Text = "Return"
End With

Update_Val (16) 'find premium costs for 16 yrs of data
Worksheets("Specs").Range("N4") = Premium_Calc()
Call Return_Data(Premium_Calc(), 4)
Set GDD_Input = Worksheets("OutlookGraphs").Range("D1:D23")
Set Derivative_Output = Worksheets("OutlookGraphs").Range("E1:E23")
Set Crop_Relation = Worksheets("OutlookGraphs").Range("F1:F23")

With Outlook_2012 'plot return graph
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Return"
    .SeriesCollection(1).Values = Derivative_Output
    .SeriesCollection(1).XValues = GDD_Input
    .SeriesCollection(2).Name = "Crop Growth"
    .SeriesCollection(2).Values = Crop_Relation
    .SeriesCollection(2).XValues = GDD_Input
    .ChartType = xlLine
    .HasTitle = True
    .ChartTitle.Text = "2012 Derivative Return"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "GDD"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "Return"

End With
Update_Val (17) 'find premium costs for 17 yrs of data
Worksheets("Specs").Range("N5") = Premium_Calc()
Call Return_Data(Premium_Calc(), 7)
Set GDD_Input = Worksheets("OutlookGraphs").Range("G1:G23")
```

```
Set Derivative_Output = Worksheets("OutlookGraphs").Range("H1:H23")
Set Crop_Relation = Worksheets("OutlookGraphs").Range("I1:I23")

With Outlook_2013 'plot return graph
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Return"
    .SeriesCollection(1).Values = Derivative_Output
    .SeriesCollection(1).XValues = GDD_Input
    .SeriesCollection(2).Name = "Crop Growth"
    .SeriesCollection(2).Values = Crop_Relation
    .SeriesCollection(2).XValues = GDD_Input
    .ChartType = xlLine
    .HasTitle = True
    .ChartTitle.Text = "2013 Derivative Return"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "GDD"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "Return"

End With
Update_Val (18) 'find premium costs for 18 yrs of data
Worksheets("Specs").Range("N6") = Premium_Calc()
Call Return_Data(Premium_Calc(), 10)
Set GDD_Input = Worksheets("OutlookGraphs").Range("J1:J23")
Set Derivative_Output = Worksheets("OutlookGraphs").Range("K1:K23")
Set Crop_Relation = Worksheets("OutlookGraphs").Range("L1:L23")

With Outlook_2014 'plot return graph
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Return"
```

```
    .SeriesCollection(1).Values = Derivative_Output
    .SeriesCollection(1).XValues = GDD_Input
    .SeriesCollection(2).Name = "Crop Growth"
    .SeriesCollection(2).Values = Crop_Relation
    .SeriesCollection(2).XValues = GDD_Input
    .ChartType = xlLine
    .HasTitle = True
    .ChartTitle.Text = "2014 Derivative Return"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "GDD"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "Return"
    '.Axes(xlCategory).MinimumScale = 650
    .Axes(xlCategory).TickLabelSpacing = 100

End With
Update_Val (19) 'find premium costs for 19 yrs of data
Worksheets("Specs").Range("N7") = Premium_Calc()
Call Return_Data(Premium_Calc(), 13)
Set GDD_Input = Worksheets("OutlookGraphs").Range("M1:M23")
Set Derivative_Output = Worksheets("OutlookGraphs").Range("N1:N23")
Set Crop_Relation = Worksheets("OutlookGraphs").Range("O1:O23")

With Outlook_2015 'plot return graph
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Return"
    .SeriesCollection(1).Values = Derivative_Output
    .SeriesCollection(1).XValues = GDD_Input
    .SeriesCollection(2).Name = "Crop Worth"
    .SeriesCollection(2).Values = Crop_Relation
    .SeriesCollection(2).XValues = GDD_Input
```

```
    .ChartType = xlLine
    .HasTitle = True
    .ChartTitle.Text = "2015 Derivative Return"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "GDD"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "Return"
    '.Axes(xlCategory).MinimumScale = 650
    .Axes(xlCategory).TickLabelSpacing = 100

End With
Update_Val (20) 'next year premium cost
'Current_PutCost1 = EP_Put()
Current_Premium.value = Premium_Calc()
Worksheets("Specs").Range("M8") = Premium_Calc()
Worksheets("Specs").Range("N8") = Premium_Calc()



For Count = 1 To 5 'for each of check years, find yield profit, returns, and losses, then record
Update_Val (14 + Count)
Worksheets("Specs").Range("O" & CStr(Count + 2)) = Derivative_Return(Worksheets("Specs").Range("G" & CStr(Count + 31)))
Worksheets("Specs").Range("P" & CStr(Count + 2)) = Crop_Val * Worksheets("Specs").Range("J" & CStr(31 + Count)) * AreaInput.value
'calculates the worth of actual farmer yield
If (Worksheets("Specs").Range("Q" & CStr(Count + 2)) < 0) Then
Worksheets("Specs").Range("S" & CStr(Count + 2)) = Worksheets("Specs").Range("P" & CStr(Count + 2)) +
Worksheets("Specs").Range("Q" & CStr(Count + 2))
Worksheets("Specs").Range("T" & CStr(Count + 2)) = Abs(Worksheets("Specs").Range("Q" & CStr(Count + 2)))
Worksheets("Specs").Range("U" & CStr(Count + 2)) = 0
Else
Worksheets("Specs").Range("S" & CStr(Count + 2)) = Worksheets("Specs").Range("P" & CStr(Count + 2))
Worksheets("Specs").Range("T" & CStr(Count + 2)) = 0
```

```
Worksheets("Specs").Range("U" & CStr(Count + 2)) = Worksheets("Specs").Range("Q" & CStr(Count + 2))
End If

Next Count



Set Returns = Worksheets("Specs").Range("U3:U7")
Set X_Axis = Worksheets("Specs").Range("M3:M7")
Set Loss_Margins = Worksheets("Specs").Range("T3:T7")
Set ProfitMargins_Cht = Worksheets("Calculations").Shapes.AddChart(xlColumnClustered).Chart 'create chart
Set Yield_Profit = Worksheets("Specs").Range("S3:S7")

'create chart
Worksheets("Calculations").Activate

With ProfitMargins_Cht 'produces the main profit chart
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Yield Profit"
    .SeriesCollection(2).Name = "Return"
    .SeriesCollection(3).Name = "Loss"
    .SeriesCollection(1).Values = Yield_Profit
    .SeriesCollection(1).XValues = X_Axis
    .SeriesCollection(2).Values = Returns
    .SeriesCollection(2).XValues = X_Axis
    .SeriesCollection(3).Values = Loss_Margins
    .SeriesCollection(3).XValues = X_Axis
    .SeriesCollection(3).Select
    With Selection.Format.Fill
    .Patterned (7)
```

```
    .ForeColor.RGB = RGB(255, 255, 255)
    .BackColor.RGB = RGB(27, 161, 226)
    End With

    .ChartType = xlColumnStacked
    .HasTitle = True
    .ChartTitle.Text = "Derivative Effect"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "Year"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "Net Profit"
End With
Worksheets("Calculations").ChartObjects.Height = Net_Stats.Height
Worksheets("Calculations").ChartObjects.Width = Net_Stats.Width
imageName = Application.DefaultFilePath & Application.PathSeparator & "ProfitMargins.gif"
ProfitMargins_Cht.Export Filename:=imageName 'make chart an image
Worksheets("Calculations").ChartObjects(1).Delete 'delete chart on the excel page
Application.ScreenUpdating = True
ValueCalculator.Net_Stats.Picture = LoadPicture(imageName) 'show chart on interface


Call Return_Data(Current_Premium.value, 16)
Set GDD_Input = Worksheets("OutlookGraphs").Range("P1:P23")
Set Derivative_Output = Worksheets("OutlookGraphs").Range("Q1:Q23")
Set Crop_Relation = Worksheets("OutlookGraphs").Range("R1:R23")
Set Outlook = Worksheets("Calculations").Shapes.AddChart(xlColumnClustered).Chart 'create chart

With Outlook 'plot return graph
    .SeriesCollection.NewSeries
    .SeriesCollection.NewSeries
    .SeriesCollection(1).Name = "Return"
    .SeriesCollection(1).Values = Derivative_Output
```

```
    .SeriesCollection(1).XValues = GDD_Input
    .SeriesCollection(2).Name = "Yield Worth"
    .SeriesCollection(2).Values = Crop_Relation
    .SeriesCollection(2).XValues = GDD_Input
    .ChartType = xlLine
    .HasTitle = True
    .ChartTitle.Text = "Derivative Return"
    .Axes(xlCategory).HasTitle = True
    .Axes(xlCategory).AxisTitle.Text = "GDD"
    .Axes(xlValue).HasTitle = True
    .Axes(xlValue).AxisTitle.Text = "Value ($)"
    .Axes(xlCategory).TickLabelSpacing = 200
    .Axes(xlCategory).TickLabels.NumberFormat = "0"

End With

Worksheets("Calculations").ChartObjects.Height = Return_Outlook.Height
Worksheets("Calculations").ChartObjects.Width = Return_Outlook.Width
imageName = Application.DefaultFilePath & Application.PathSeparator & "Outlook.gif"
Outlook.Export Filename:=imageName 'make chart an image
Worksheets("Calculations").ChartObjects(1).Delete 'delete chart on the excel page
Application.ScreenUpdating = True
ValueCalculator.Return_Outlook.Picture = LoadPicture(imageName) 'show chart on interface
Worksheets("Specs").Activate

End Sub

Function Return_Data(Premium As Double, Column As Integer) 'records return data in excel sheet, Column is the start column of data
Dim Count As Integer
For Count = 50 To 500 Step 50
Worksheets("OutlookGraphs").Range(Letter_Array(Column) & CStr((Count / 50))) = (K1 - 550) + Count
Next Count
```

```
Worksheets("OutlookGraphs").Range(Letter_Array(Column) & "11") = K1
Worksheets("OutlookGraphs").Range(Letter_Array(Column) & "12") = Projected_GDD
Worksheets("OutlookGraphs").Range(Letter_Array(Column) & "13") = K2
For Count = 50 To 500 Step 50
Worksheets("OutlookGraphs").Range(Letter_Array(Column) & CStr((Count / 50) + 13)) = K2 + Count
Next Count
For Count = 1 To 23
Worksheets("OutlookGraphs").Range(Letter_Array(Column + 1) & CStr(Count)) =
Derivative_Return(Worksheets("OutlookGraphs").Range(Letter_Array(Column) & CStr(Count))) - Premium
Next Count
For Count = 1 To 23
Worksheets("OutlookGraphs").Range(Letter_Array(Column + 2) & CStr(Count)) =
Predict_YieldEq(Worksheets("OutlookGraphs").Range(Letter_Array(Column) & CStr(Count))) * AreaInput.value * Crop_Val
Next Count
End Function

Sub Show_Accuracy() 'show accuracy values
Dim hold As Double
Dim val1 As Double
Dim val2 As Double
Dim val3 As Double
Dim val4 As Double
Dim val5 As Double

GDDer2011.value = Worksheets("Specs").Range("H32")
GDDer2012.value = Worksheets("Specs").Range("H33")
GDDer2013.value = Worksheets("Specs").Range("H34")
GDDer2014.value = Worksheets("Specs").Range("H35")
GDDer2015.value = Worksheets("Specs").Range("H36")

GDDerAVG.value = Worksheets("Specs").Range("H32") + Worksheets("Specs").Range("H33") + Worksheets("Specs").Range("H34")
GDDerAVG.value = GDDerAVG.value + Worksheets("Specs").Range("H35") + Worksheets("Specs").Range("H36")
```

```
GDDerAVG.value = GDDerAVG.value / 5

Yielder2011.value = Worksheets("Specs").Range("K32")
Yielder2012.value = Worksheets("Specs").Range("K33")
Yielder2013.value = Worksheets("Specs").Range("K34")
Yielder2014.value = Worksheets("Specs").Range("K35")
Yielder2015.value = Worksheets("Specs").Range("K36")

YielderAVG.value = Worksheets("Specs").Range("K32") + Worksheets("Specs").Range("K33") + Worksheets("Specs").Range("K34")
YielderAVG.value = YielderAVG.value + Worksheets("Specs").Range("K35") + Worksheets("Specs").Range("K36")
YielderAVG.value = YielderAVG.value / 5

End Sub

Private Sub AreaInput_Change()
 If Not IsNumeric(AreaInput.value) And AreaInput.value <> vbNullString Then
 MsgBox "Please Enter Numeric Number of Tons"
 AreaInput.value = 0
 End If
End Sub

Private Sub Tick_Button_SpinUp() 'code for adjusting tick size, no safety in place!
Tick_Input.value = Tick_Input.value + 1
D = Tick_Input.value
Call Calculate_Click
End Sub

Private Sub Tick_Button_SpinDown() 'adjust tick size, no saftey in place!
Tick_Input.value = Tick_Input.value - 1
D = Tick_Input.value
Call Calculate_Click
End Sub
```

```
Private Sub Tick_Input_Change() 'entering tick value
If Not IsNumeric(Tick_Input.value) And Tick_Input.value <> vbNullString Then
 MsgBox "Please Enter Numeric Number"
 AreaInput.value = 0
 ElseIf Tick_Input.value <> vbNullString Then
 D = Tick_Input.value
 End If
End Sub

Private Sub UserForm_Initialize()
'Suppose to position the screen on start up, however does not work
Me.StartUpPosition = 0
Dim Top As Double, Left As Double
Top = Abs(Application.Top) + _
(Application.Height - ActiveWindow.Height) + _
(Application.UsableHeight - ActiveWindow.UsableHeight)
Left = Abs(Application.Left) + (Application.Width) - (Me.Width + 10)
Me.Top = Top
Me.Left = Left



'clear graphs on outlook page
If Worksheets("OutlookGraphs").ChartObjects.Count > 0 Then
      Worksheets("OutlookGraphs").ChartObjects.Delete
   End If



Dim counter As Integer

'Clear error outputs
```

```
GDDer2011.value = 0

GDDer2012.value = 0

GDDer2013.value = 0

GDDer2014.value = 0

GDDer2015.value = 0

GDDerAVG.value = 0

Yielder2011.value = 0

Yielder2012.value = 0

Yielder2013.value = 0

Yielder2014.value = 0

Yielder2015.value = 0

YielderAVG.value = 0


'fill letter array

Letter_Array(1) = "A"

Letter_Array(2) = "B"

Letter_Array(3) = "C"

Letter_Array(4) = "D"

Letter_Array(5) = "E"

Letter_Array(6) = "F"

Letter_Array(7) = "G"

Letter_Array(8) = "H"

Letter_Array(9) = "I"

Letter_Array(10) = "J"

Letter_Array(11) = "K"

Letter_Array(12) = "L"

Letter_Array(13) = "M"

Letter_Array(14) = "N"

Letter_Array(15) = "O"

Letter_Array(16) = "P"

Letter_Array(17) = "Q"

Letter_Array(18) = "R"
```

```
Letter_Array(19) = "S"
Letter_Array(20) = "T"
Letter_Array(21) = "U"
Letter_Array(22) = "V"
Letter_Array(23) = "W"
Letter_Array(24) = "X"
Letter_Array(25) = "Y"
Letter_Array(26) = "Z"

'fill Crop selection
CropChoice.Clear
CropChoice.value = ""



'clear yield and GDD vals
For counter = 1 To 20
Worksheets("Specs").Range("J" & CStr(counter + 2)) = Null
Worksheets("Specs").Range("I" & CStr(counter + 2)) = Null
Next counter

Dim Count As Integer
For Count = 3 To 21 '18 possible crops can be added
If Not IsEmpty(Worksheets("Specs").Range("B" & CStr(Count))) Then
CropChoice.AddItem Worksheets("Specs").Range("B" & CStr(Count))
End If
Next Count

'fill Location selection
Location.Clear
Location.value = ""
Location.AddItem "Moscow"
Location.AddItem "Krasnodar"
```

```
Location.AddItem "Omsk"

'Set Variables
Crop_Type = " "
Crop_Val = 0 'wait for value
Crop_Region = 0 'wait for value
Crop_Day = 0 'wait for input
Crop_Month = 0 'wait for input
Temp_EndCell = 0 'wait for input


'init cell locations of years
Num_Years(1) = 0
Num_Years(2) = 0
Num_Years(3) = 0
Num_Years(4) = 0
Num_Years(5) = 0
Num_Years(6) = 0
Num_Years(7) = 0
Num_Years(8) = 0
Num_Years(9) = 0
Num_Years(10) = 0

Date_Track = 0

Predicted_Yield.value = 0 ' clear predicted yield
Predicted_GDD.value = 0 ' clear predicted GDD
AreaInput.value = 0 ' clear area input

'year that data goes back to
Data_StartYr = 1996
Num_DataYr = Worksheets("Specs").Range("F15")
```

```
'load derivative values

D = Worksheets("Specs").Range("F3") 'tick size

Tick_Input.value = D

U = Worksheets("Specs").Range("F4")

DEV = Worksheets("Specs").Range("F5")

R = Worksheets("Specs").Range("F8")

RL = Worksheets("Specs").Range("F9")

Contract_Range = Worksheets("Specs").Range("F10")

m = Worksheets("Specs").Range("F11")

n = Worksheets("Specs").Range("F12")


'testing

'Call_Divisions(1) = 1.2

'Call_Divisions(2) = 1.4

'Call_Divisions(3) = 1.6

'Call_Divisions(4) = 1.8

'Call_Divisions(5) = 2

'

'Put_Divisions(1) = 0.8

'Put_Divisions(2) = 0.6

'Put_Divisions(3) = 0.4

'Put_Divisions(4) = 0.2

'Put_Divisions(5) = 0


End Sub
```