Assessing Opportunities to Improve Potato Farming with Smart Agriculture: The Case of Notia, Greece

AMERICAN FARM SCHOOL

WPI

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Abstract

Smart agriculture, the use of proven farming strategies including techniques, technologies and cultivar varieties, increases productivity and reduces costs. Both established and new farmers can benefit by incorporating smart agriculture strategies; yet, there are economic, historic, political, and social complexities that influence how these approaches are considered. Using qualitative methods, a case study and interviews, this project explored engagements with smart agriculture by young, formally educated farmers and a community of established potato farmers in northern Greece. We also developed a model for predicting fungicide application time to prevent a potato crop disease. Findings identify that age, expectations, and established trust influence engagement with smart agriculture.

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Chapter 1: Introduction

Smart Agriculture is the process of using highly effective farming strategies to increase yields and lower costs (European GNSS Agency, 2014). These strategies can come in the form of efficient techniques, new varieties of cultivars, and new technologies to optimize the use of inputs, such as fertilizers, fungicides, seeds, etc., so less are needed during the growing season (Adam, 2015). Money saved from fewer inputs can be reinvested into buying new equipment and technology, which would also aid in creating higher yields and further reduce inputs (European GNSS Agency, 2014). Although smart agriculture has the potential to increase productivity and decrease reliance on inputs, there are economic and social complexities that need to be taken into account when creating these effective farming strategies (Michalopoulos, 2015).

One community that can benefit from smart agriculture is in Notia, Greece. Located in the region of Central Macedonia, Notia is home to 370 people, of which 240 are farmers (E. Vergos, personal communication, March 15, 2016). McCain Foods Company, a multinational corporation based in Canada with a branch in Greece, wanted to assist Notia's economic condition with a corporate social responsibility initiative called "Karpos Frontidas," which translates to Care Fruit (Diamantopoulos, 2015).

In 2015, McCain signed contracts with 25 farmers in Notia to grow potatoes. For the farmers, the incentives to join the program included a binding agreement with a supermarket chain to sell their potatoes, access to credits to buy machinery and resources, and a reduced price on seed potatoes (Diamantopoulos, 2015). McCain also partnered with, our sponsor, the School of Professional Education (SPE) at the American Farm School (AFS) to provide extension services to help Notia farmers meet McCain's demand for a new crop, the Servane potato, which farmers in Notia had not cultivated.

However, in the first year of the program, the farmers in Notia failed to meet the production goals for many reasons: questions of trust among the stakeholders involved in the program, an older generation being cautious about changing their farming practices, and difficulties adapting the Servane growing protocol to local conditions. Refining the cultivation protocol with field data could increase the yield of the farmers' crops. Our project worked with the SPE to identify opportunities to use a blight prediction model, based on weather data from the village, to change cultivation practices around fungicide use. To understand what factors could promote such innovation, we conducted a case study with a farmer who has used smart technology in his farming practices. With these insights about successful uses of a more information rich approach to farming, we then conducted field based research in Notia to assess this dynamic.

Chapter 2: Literature Review

2.1 Greece's Potato Industry

Greece's potato sector has declined in production and consumption rates since the start of the economic crisis. In 2007, Greece produced 943,196 metric tons of potatoes, while in 2011, Greece produced only 757,820 metric tons (Food and Agriculture Organization of the United Nations [FAO], 2015). In terms of consumption, Greeks consumed 79.42 kg/capita per year in 2007 and that has decreased to 65.38 kg/capita per year in 2011 (FAO, 2015). Prior to the crisis, Greece dedicated 23,680 hectares of land to potato farming in 2007, but that number has declined to 18,530 hectares in 2013 (Statistical Office of the European Communities [EUROSTAT], 2015a). In prior years, along with having higher production, the Greek farmers also received Common Agricultural Policy (CAP) subsidies from the European Union, which "created amongst farmers the feeling of stability and that their incomes were guaranteed and safe" (Koutsou, Partalidou, & Ragkos, 2014). However, in recent years these CAP subsidies have also started to decrease (Pispini, 2014).

2.2 European Union Subsidies in Greece

The Common Agricultural Policy (CAP) was developed by the European Union (EU) to implement agriculture subsidies and programs to increase food production and farm incomes. Since the establishment of the CAP in the 1960's, it has continuously undergone reforms to encourage growth among the agriculture industry (Klonaris & Vlahos, 2012). In CAP there are two pillars, the first pillar is a single payment scheme which is mainly direct payments to farmers and account for 75% of the total EU CAP. The second pillar is devoted to promoting economic, environmental, and social development in rural areas ("Understanding the EU," 2014). Greece's agricultural sector has one of the highest dependencies on CAP subsidies in the EU (National Bank of Greece, 2015). In 2013, the direct CAP payments were 384 €/hectare in Greece while Europe had an average of 293 €/hectare as seen in Figure 1 (National Bank of Greece, 2015).

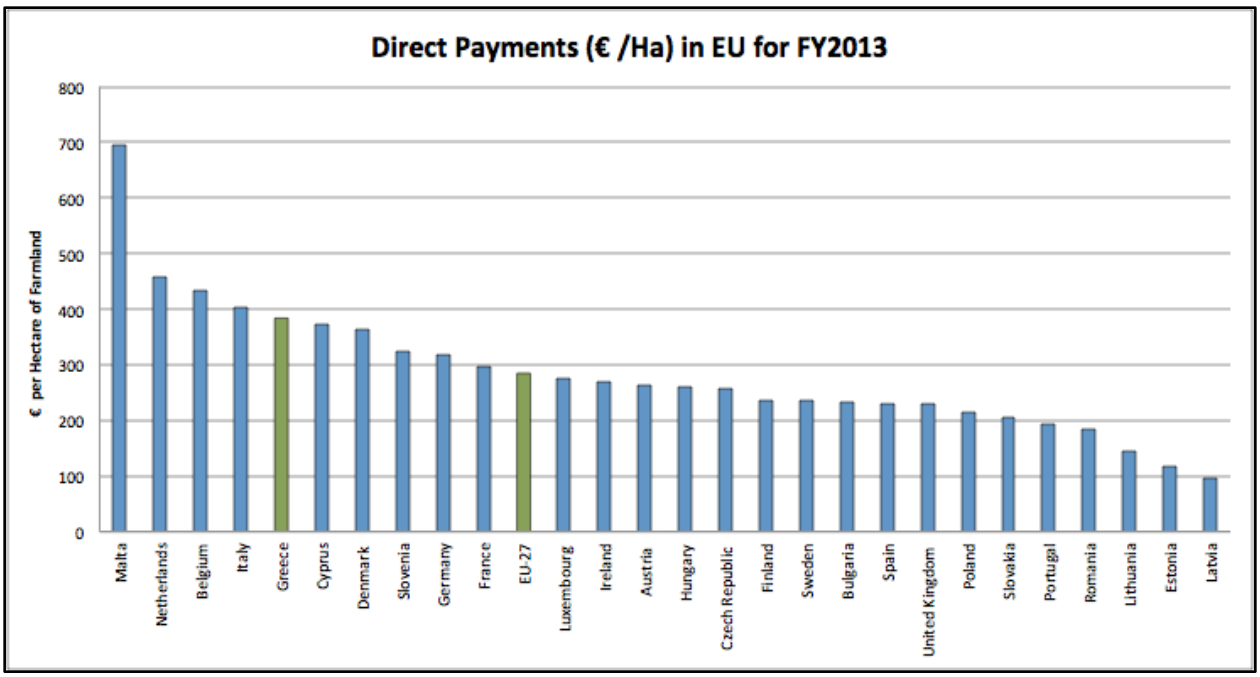

Figure 1: Graph of CAP direct payments to each country in the EU & their average (EU-27) (Scottish Government, 2013)

In 2014, the CAP was reviewed by the European Union and established new reforms cutting the amount of subsidies available to farmers in Greece. One reason the CAP subsidies were reduced in Greece is because the Land Parcel Identification System (LPIS) was over estimating land usage of farmers, giving farmers an unnecessary amount of aid (Ioannou, 2014). Due to these cuts, some farmers may end up bankrupt since they could lose up to 60% of direct aid (Pispini, 2014). Therefore, the Greek farmers need to find efficient and sustainable farming solutions to keep up with the global economy (Koutsou et al., 2014). Greece has opportunities to create high-quality production due to its climate and location, however, there is a need to innovate to fully harness its potential (National Bank of Greece, 2015).

2.3 The Potential and Challenges of Implementing Smart Agriculture

Smart Agriculture is the process of using highly effective farming strategies to increase yields and lower costs (European GNSS Agency, 2014). It consists of using efficient techniques, new varieties of crops, and new technology (Adam, 2015). With these practices, there is a potential opportunity to increase farmers' incomes and create a more sustainable production (European GNSS Agency, 2014).

One technique involves the collection of real-time data on weather, soil and air quality, so strategies can be made by the farmer in order to reduce costs associated with labor, inputs and time (International Business Machines [IBM], 2012). For example, if there is heavy rain predicted, the farmer can refrain from putting down fertilizers that would wash away (IBM, 2012). This same information can also be used to create disease forecasting models. These models gather data on weather conditions and output if there is any risk of disease for their crops, which can be used to justify treatment sprays (Exadaktylou, Rossi, & Thomidis, 2010). In Imathia, Greece, a study was conducted to prove the importance of incorporating this type of data with the farmers' decision to apply fungicides. Information from the weather data was entered into the disease predicting model to determine the risk

level of leaf curl for peaches. By utilizing this smart agriculture practice, the farmers in Imathia would be able to reduce the number of fungicide applications compared to a conventional system without increasing risk of disease, and therefore becoming more cost efficient in applying fungicides (Exadaktylou et. al, 2010).

The use of new cultivar varieties, another smart agriculture technique, has been a major factor in improving farmers' income (International Union for the Protection of New Varieties of Plants [UPOV], 2015). New cultivar varieties that improve yield, quality, and disease resistance increase the productivity of a farm (UPOV, 2015). One example includes new cabbage varieties that were introduced to farmers in Kosovo which would increase their yields by 57% compared to their traditional variety (Kaciu, 2013). As seen in Kosovo, testing new cultivar varieties can drastically improve the productivity of farms.

With the savings from the previous techniques, this money can be reinvested into new equipment to continue optimizing agricultural operations (European GNSS Agency, 2014). New sensors, weather stations, and other technologies can help farmers in many ways. One way consists of determining the optimal rate of application for chemical inputs, thereby reducing the amount used on the fields (Michalopoulos, 2015). One example is a sensor based Variable Rate Fertilizer (VRF), which uses a near-infrared (NIR) sensor connected to a micro-computer to calculate an optimal amount of fertilizer application throughout the field, saving farmers' costs associated with fertilizer (Fulton and Taylor, 2010).

Farmers can recognize many potential benefits of using smart agriculture, however they face challenges when switching from conventional practices to these new methods (Oxouzi & Papanagiotou, 2010). Some farmers choose to stick to their original practices because they lack the technical skills, especially in computing, to adopt different farming methods (Kitchen & Snyder, 2002). This is especially difficult with farmers who have been using their current practices for generations. Researchers found that farmers who were not willing to switch were often older, had more agricultural experience, and did not attend a higher education institution (Oxouzi & Papanagiotou, 2010). A study conducted in Greece examined two rural villages, Foufas and Kefalas to determine how willing the farmers were to change their current farming practices. In Foufas, where they commonly farm potatoes, 77.3% of farmers were in the age group of 41-65 years old. These farmers were less likely to change their conventional farming methods to more sustainable farming practices. Meanwhile in Kefalas, where they farm olives, 50% of the farmers were between 41-65, and the remainder between 21-40 years old. Farmers in this region, especially the younger farmers, were more inclined to adopt the new methods because they saw how the changes could help their crops (Koutsoukos & Iakovidou, 2013).

2.4 Small Scale Potato Farming in Northern Greece: The Case of Notia

The implementation of smart agriculture is currently taking place in a small, impoverished farming village roughly two hours northwest of Thessaloniki named Notia. The village of Notia is situated in the mountains of the Central Macedonian region of Greece as seen in Figure 2. The village consists of approximately 370 people, of which 240 are involved in farming (E. Vergos, personal communication, March 15, 2016). In the 1920's, many families migrated from Asia Minor to the village of Notia during the exchange of populations between Turkey and Greece (E. Vergos, personal communication, March 15, 2016). These families sustained themselves through agriculture and passed down their traditional farming practices from generation to generation. From this land, farmers in Notia produce a variety of crops consisting of corn, cherries and potatoes (E. Vergos, personal communication, March 15, 2016).

Figure 2: Farmland in Notia, Greece

Looking more broadly, the region of Central Macedonia produces around 7% of Greece's potatoes on 1385 hectares of land (British Potato Council, 2006). Most farmers in Notia own an average of seven hectares of land, of which only a small portion is dedicated to potatoes (K. Zoukidis, personal communication, April 1, 2016). At one point, farmers in the area received a large amount of assistance from the European Union's CAP subsidies, but these subsidies have been reduced, forcing them to find additional ways to support their families (Pispini, 2013). For example, in 2007, farmers in the Central Macedonian region earned some €17.5 million on their products. However, as the economic crisis grew in Greece, the earnings dropped to €15 million in 2011 (Thanopoulos, 2011).

In addition to the lack of subsidies, development of the agriculture sector in Greece is hindered by a lack of extension service education (Georgiadis, 2016). In the past, extension services aided many farmers similar to the ones in Notia. Extension services aim "...to convey important information to adults, new knowledge and appropriate skills with innovative ways in order to improve their competitiveness in the labor market, to enhance their effectiveness in the business sector and improve their manufactured products and their quality of life" (American Farm School, 2016).

Over the last 30 or so years, extension services have dwindled due to structural change from a practical service to more administrative roles in the 1980's (E. Vergos, personal communication, March 15, 2016; Roling & Wagemakers, 2000). However, against this trend, the School of Professional Education (SPE), an extension service at the American Farm School in Thessaloniki, Greece, is working with farmers in Notia to implement smart agriculture. The extension service will teach the farmers about the usefulness of soil and tissue analysis, being a tool which can give knowledge to produce better quality and quantity of potatoes. These skills will save the farmers time and effort in their daily farming practices, leading to a sustainable potato industry. In performing these tasks, the SPE is working in collaboration with the McCain Foods Corporation (E. Vergos, personal communication, February 1, 2016).

McCain Foods is a Canadian food manufacturer looking to strengthen its Greek-Canadian relations by taking part in a new corporate social responsibility (CSR) initiative, *Karpos Frontidas*, translated to Care Fruit (Diamantopoulos, 2015). Typically, a CSR project identifies areas of need, such as Notia, and tries to develop successful and sustainable farming practices to help bring economic stability to communities. However, many people see CSRs to be mainly public relation matters and they debate its legitimacy (McWilliams, 2000). Some corporate social responsibilities use their resources to increase the company's profits, focusing on the economic and political position of the company rather than the community they are trying to help (Cadbury, 2006). Regardless of the personal gain of the company, CSRs can result in many economic and social benefits for the community (Diamantopoulos, 2015).

McCain's CSR aims to increase Notia's potato production from 900 metric tons per season to 2000 metric tons in three years. Additionally, McCain hopes to build a self-sustaining business model that can be used to combine financial

performance with their social mission ("McCain Continues its Social Mission," 2015). In other words, McCain is attempting to create an efficient and lasting potato farming industry in the small village of Notia, where they believe there is potential to improve their current farming industry. To begin their CSR, McCain representatives travelled to the village, advertising its program, and in the end, 25 farmers signed a contract to be a part of its piloting year (Diamantopoulos, 2015). As part of the program, farmers were required to use a new variety of potato seed, Servane, which they purchased from McCain at a reduced price.

The Servane tuber is long-oval shaped with yellow skin (Figure 3), and it was bred in Châteauneuf-du-Faou, France in 1998 (Canadian Food Inspection Agency, 2016). This cultivar was specifically designed for the French climate and soil and made to be more blight resistant than other potato breeds. This blight resistance is an important feature for the farmers in Notia, but because of the different climates between France and Greece, there was an uncertainty of how well the potato will grow.

Figure 3: Servane potato sprout (Canadian Food Inspection Agency, 2006)

Along with the new variety of potato, McCain has developed a protocol that explains the details of planting and nurturing the crop. McCain's protocol covers a wide variety of parameters: pH, irrigation, planting procedures, fertilizer and pesticide application, harvesting and postharvest storage. (E. Vergos, personal communication, March 15, 2016). Since the climate and soil in Notia is different from France, the protocol needs to be adjusted accordingly.

Currently, the SPE is working with an agronomist hired by McCain to guide the farmers in using new techniques listed in the protocol and introduce them to smart agriculture. Specifically, one smart agriculture technique that the SPE wants to introduce is the use of a data analysis from a local weather station to help farmers better anticipate late blight conditions (E. Vergos, personal communication, April 4, 2016).

The telemetric weather station, as seen in Figure 4, has been implemented in Notia to send data from the fields to a web server, which can be accessed by the farmer and collaborators (A. Gertsis, personal communication February 18, 2016). The weather station collects data on wind speed and direction, barometric pressure, air temperature, relative humidity, precipitation, sunlight radiation, soil temperature, soil moisture, leaf wetness, and much more depending on what sensors are connected to it (A. Gertsis, personal communication, February 18, 2016). The weather stations is more reliable than regional weather reports on the news or the internet because it gives the specific conditions on the field (Duval, 1998). This in-field weather information allows the farmers to complete critical practices when they are relevant to their crops. This is especially important when it comes to disease management.

Figure 4: Telemetric Weather Station in Notia

A common disease found while growing potatoes in Notia is called late blight which is shown in Figure 5 (E. Vergos, personal communication, March 15, 2016). Caused by the fungus *Phytophthora infestans*, late blight is a disease which has destroyed billions of dollars worth of potato crops worldwide (Ahmad, Arora, & Singh, 2012). Its severity changes annually, from nonexistent to disastrous proportions in which all crops are lost (Ahmad et al., 2012). Late blight occurs in high humidity and moderate temperatures, which aligns with Notia's growing conditions where the average temperatures ranges from 3 degrees Celsius to 34 degrees Celsius (Ahmad et al., 2012; "Notia Monthly Climate Average, Greece", 2012). When the conditions are right for late blight, the disease can infest the crop at approximately 20 to 80 days after planting (Tantowijoyo & Fliert, 2006). Due to the potatoes' susceptibility to late blight, if farmers do not use preventative measures, they could encounter a significant loss of yields and income (Ahmad et al., 2012).

Figure 5: A potato tuber affected by late blight (Kuepper & Sullivan, 2004)

The most common way of preventing diseases, specifically late blight, in potato crops is by using fungicide sprays. However, fungicides are only effective before the fungal infection occurs, so farmers must spray their crops before it is infected as seen in Figure 6 (Schumann and D'Arcy, 2000). Traditionally, potato farmers in Europe first start fungicide sprays when the plant reaches a height of 15cm and continue to spray on a time interval (Duval, 1998). However, this method often uses an unnecessary amount of fungicides before late blight would actually infect the potato crop (Duval, 1998). One smart agriculture practice, which helps reduce the number of unnecessary fungicide sprays, is a late blight forecasting model (Duval, 1998). This model gives an advance warning of late blight, allowing the farmers to apply fungicides at a later time but still before late blight infects their crops (Nærstad et al., 2009). This model uses weather data to predict if conditions are ideal for late blight.

Models such as the Smith Period, Negative Prognosis, Blitecast, NegFry, and Sparks use temperature and relative humidity on a per hour basis to determine the likelihood of late blight (Taylor, Hardwick, Bradshaw, & Hall, 2003). Each model uses these readings in its calculations to predict when blight would occur (Bloom, Broome,

Underwood, & Guzman-Plazola, 2014). Due to variance in how the models calculate late blight, it is possible for these models to underestimate or overestimate the likelihood of blight, thus the model must be verified in the relevant area through extensive testing (Bloom et al., 2014, Taylor et al., 2003). Once the model is verified for the region, a farmer can use the data to fine tune the frequency and amount of fungicide sprayed onto the crops compared to a traditional spray program (Bloom et al., 2014).

Figure 6: "Fungicide-treated potatoes (background) and non-fungicide treated potatoes (foreground) in an experimental field trial" (Schumann and D'Arcy, 2000)

Chapter 3: Methodology

The main goal of the project is to assess the opportunity to implement smart agriculture into potato production in Notia. While there are benefits from innovating and using smart agriculture, uncertainties among the farmers can arise when encountering the challenges of implementing these kinds of technology into their traditional ways of farming. Our project will work towards this goal through three main objectives:

1. Examine how smart agriculture can be used to innovate farming practices
2. Analyze late blight prediction models which could alter fungicide application practices and reduce blight incidence in Notia
3. Understand the social dynamic of implementing smart agriculture in Notia

3.1 Examine How Smart Agriculture Can be Used to Innovate Farming Practices

We conducted an illustrative case study with a graduate from Perrotis College, in Thessaloniki, Greece, who is using smart agriculture practices in his farming. The illustrative case study gave us an opportunity to gather qualitative data and better understand how smart agriculture was implemented by one individual (Becker et al., 2012). Savvas Kilatzidis, graduated with a degree in Environmental Systems Management and a concentration in precision agriculture. Precision agriculture is a technique encompassed in smart agriculture. It uses tools such as geographic information systems (GIS), global positioning systems (GPS), and other sensors to optimize farming practices by reducing the amount of inputs required. (McBratney, Whelan, Ancev, & Bouma, 2005). We visited Kilatzidis's farm on Saturday, April 9th in the afternoon where he showed us his farming equipment and his fields, which total 1,000 hectares. We used a multimodal approach to collecting data which included informal discussions and field observations as part of the case study (Becker et al., 2012). The case study focused on topics such as his motivation to use smart agriculture, the benefits that accrued from the technology, and the extent to which his workers were able or willing to employ new farming practices based on these technologies. The questions we explored in our case study can be found in Appendix A.

3.2 Analyze Late Blight Prediction Models Which Could Alter Fungicide Application Practices and Reduce Blight Incidence in Notia

We also conducted semi-structured interviews with smart agriculture experts, Professor Konstantinos Zoukidis and Dr. Athanasios Gertsis from the SPE, to obtain a greater understanding of how late blight predicting models could be analyzed. Our interviews focused on how late blight affects the potatoes in Notia, what the SPE expects the model to predict, and what the SPE plans to do with the model after it is given to them. With the consent from the interviewees, we recorded the discussion, using both audio and video devices. See Appendix B for the verbal consent statement along with the key questions we asked these experts.

Late blight, as discussed in the previous chapter, affected potato quality during the past growing season. Since McCain did not provide a late blight forecasting model to the SPE, it was necessary for us to develop a tool that could use the data from the weather station in Notia. A late blight forecasting model was developed in Excel to predict the first instance of late blight. This model will provide information to the SPE so that they may inform the Notia farmers on whether or not there is a risk of late blight. We conducted research on late

blight forecasting models to determine the most viable model for Notia which fits the established criteria of reliability, accuracy, feasibility, and past validity and implementation. To develop our own model in Excel, we constructed a decision matrix analyzing five existing models: Negfry, Blitecast, Smith Period, Negative Prognosis, and Sparks.

3.3 Understand the Social Dynamics of Implementing Smart Agriculture in Notia

First, we observed two training sessions for the Notia farmers about the McCain protocol. Led by the SPE faculty, the farmers were taught how they should be planting their seeds, taking soil samples, and how to access the weather station. At the first training, we were briefly introduced to the farmers by the McCain liaison, Martha, as well as Gertsis. We had Gertsis translate the presentation in order for us to comprehend the goal of the training and the farmers' responses. During this training, we observed the farmers and their reactions towards the presentation of the McCain protocol and information from the weather station and soil analyses. We noted in our field journals the types of information that caused the farmers to interrupt or disagree. We observed topics that caused the farmers to be silent, whether that silence was from boredom, thought, or agreement. Finally, we examined the interest levels of farmers in the program based on their initiative to reach out to Gertsis at the end of the presentation.

Halfway through the second training, we conducted structured interviews with a convenience sample of seven potato farmers in the McCain program about their farming history, the Servane crop, and changing farming practices. We chose structured interviews as a way of collecting this information because of the language barrier. Since conversations could be challenging, we asked Vergos to translate our questions into Greek which were read to the farmers by a translator. Our translators were Vergos, Gertsis, Zoukidis and Anna Papakonstantinou from the SPE. We were aware that working with translators could present possible biases, one being a reactivity bias where the farmers might change their response since we were working in collaboration with the SPE (Heppner, Wampold, & Kivlighan, 2008). We had fifteen minutes to complete our interviews due to the fact that many farmers needed to return to their fields to finish seeding their potatoes. The questions we asked and their translation into Greek are found in Appendix C.

In addition to speaking with and observing the farmers, we conducted in-depth interviews with key informants involved in the McCain program. We talked with Gertsis, Vergos, Zoukidis, and Papakonstantinou. We decided to use in-depth interviews as a way to obtain this information because it gave us the opportunity to engage the key informants in largely unstructured conversations. See Appendix B for the verbal consent statement along with the questions we asked these key informants. The goals of these observations and interviews were to gain a better understanding of the McCain program and learn about each interviewee's opinions on incorporating technology into farming methods.

When analyzing the data we collected from all our in-depth and structured interviews as well as the case study with Kilatzidis, we used a modified grounded theory approach to sort and condense themes of data (Evans, 2013; Glaser 1992). We first used an open code to sort data into categories, then used selective coding to saturate the core concepts of the data (Holton, 2007). Once the data was separated into themes, we could further our analysis of the successes and challenges with adopting smart agriculture.

Chapter 4: Findings

4.1 Examine How Smart Agriculture Can be Used to Innovate Farming Practices

Sensors and GPS in machinery allow for precise application of fertilizers.

Savvas Kilatzidis graduated from Perrotis College in 2011 with a degree in Environmental Systems Management, specializing in precision agriculture. Through his education, Kilatzidis learned how geographic information system (GIS), global positioning system (GPS), and other sensors can optimize farming practices by reducing the amounts of inputs. He chose that degree so he could expand production on his family's farm. One of the biggest changes Kilatzidis made to his farm was introducing new machinery. Kilatzidis invested in a new tractor that uses GPS sensors to precisely apply fertilizers onto his crops. With this GPS tractor, there is no overlap of these sprays from row to row in the fields. The accuracy of the machine reduced the amount of inputs needed to apply on the farm. The new tractor saved Kilatzidis 3% on fuel and 72 metric tons of fertilizers per year. Along with the GPS tractor, Kilatzidis purchased a new sprayer where the desired fertilizer amount per square meter can be entered into the machine's computer. Traditionally, older sprayers will output a consistent rate of fertilizer independent of the tractor's speed. These older sprayers are inefficient at lower speeds because they apply an unnecessary amount of fertilizer. With the new sprayer, no matter what speed the tractor is moving at, the fertilizer spray will be distributed appropriately, saving Kilatzidis even more fertilizer.

Figure 7: Kilatzidis's new sprayer (top) and new GPS tractor beside an older tractor (bottom)

While there was a large upfront cost for the machines, through subsidies from the European Union, he was able to afford the purchase and make up the difference with the money he saved over multiple seasons. The smart agriculture technology Kilatzidis implemented on his farm is one factor that allowed him to expand his family's business to more international markets, giving him a wider prospect for selling his crops.

Older workers on the farm were skeptical about using this sensor driven technology to reduce inputs and fearful that they could damage the technology during operations.

Although Kilatzidis was very successful introducing smart agriculture technology on his farm, he still faced challenges. Of his fourteen employees on the farm, eight refused to drive the new GPS tractor. These workers were older than the other six and had more reservations about the new machines. According to Kilatzidis, many of them were afraid of damaging the expensive equipment and did not fully trust the technology. In our interview, he stated, "They used to drive the machines with no hydraulics, nothing, everything is on their hands and legs. They cannot trust...the machines." After years of using the traditional machinery, they know how the machines run and what to do if something breaks. With the new machinery, especially the GPS tractor, the older farmers were afraid that they would operate it incorrectly, leading to damages.

Even Kilatzidis's father was wary of the new technology and didn't fully understand it. However, he could see the benefits for the business. Kilatzidis explained that, "he will say, 'Yes, it's okay, but I will not try it.'" While the older workers could also see the benefits to the farm with using this technology, they shared the same sentiments as Kilatzidis's father. Even though Savvas tried to teach them, it took a lot more time for the older workers to understand the concepts and feel comfortable with the technology. Over the years, Savvas found it too difficult and time consuming to give extensive training sessions to those who did not fully trust the concepts. Instead, Kilatzidis found it more beneficial to assign the older workers to the traditional machinery and to hire younger workers who could adjust to the new machines. Through this system, he was able to optimize the use of his machinery in the fields. As Kilatzidis continues to buy newer machines, he will have a greater need for the older farmers to learn the new technology in order to keep his farm competitive in the global market.

New cultivars can increase the quality and yield of crops when properly tested in the region.

Kilatzidis currently grows corn, wheat, and soft cereals. One smart agriculture practice Kilatzidis learned at Perrotis College was crop testing. During past growing seasons, he dedicated 20 to 50 hectares of land out of his 1000 hectare farm to test new varieties of these cultivars, hoping to find one that will give him a better yield and quality. The 20 to 50 hectares were scattered throughout different locations on his farm in order for the cultivars to grow under variable soil conditions. The new cultivars were tested for two or three years and then reevaluated to see if it would be profitable to adopt the cultivar. According to Kilatzidis, only about one in ten of the new cultivars show improvement over his main crops of corn, wheat and cereals. However, utilizing this smart agriculture tactic to find that one new cultivar is worth the effort since it can greatly increase the productivity of his farm. For a full analysis of the case study of Savvas Kilatzidis, see Appendix D.

4.2 Analyze Late Blight Prediction Models Which Could Alter Fungicide Application Practices and Reduce Blight Incidence in Notia

Reliability, accuracy, feasibility, and past validity and implementation were chosen as the determining factors when selecting a model to implement in Notia.

Through our research, we identified five models for comparison to select the best model for Notia's needs. These models included the Smith Period, Negative Prognosis, Blitecast, NegFry, and Sparks. We rated each model based on four factors: reliability, accuracy, feasibility and past validity and implementation (Taylor et al., 2003; Bloom et al., 2014). The ratings for accuracy and reliability were determined from Taylor's research, which tested the models using multiple test plots around the United Kingdom over four years (Taylor et al., 2003). The validation and implementation of each of the

models was obtained from research conducted by the University of California's Integrated Pest Management Program (Bloom et al., 2014). The feasibility of creating the model was dependent on the amount of information available for each of the models, allowing them to be programmed in Excel. In order to objectively choose the best model, we created a decision matrix which weighed the four factors mentioned above. The factors were all scaled out of five and then given a certain numerical weight to calculate the best model for Notia's purposes: reliability had a multiplication weight of four, feasibility had three, accuracy had two, and validation and implementation had one.

In this decision process, reliability had the highest multiplication factor. If the model is wrong in predicting when late blight occurs then there is a chance that late blight had already infested the potato, ruining the quality of the crop. The judging criteria of this factor is based on data as seen in Figure 8. Class O (Overdue) represents a warning that is less than 7 days before late blight occurred, Class E (Early) represents a warning 14 or more days before late blight occurred, and Class I (Ideal) represents a warning that is between 7-14 days before late blight occurred. When Taylor analyzed the models he ignored false positives, warnings for late blight when no infestation occurred, because all of the models at some point output a false positive. On the other hand, false negatives, no warnings of late blight when an infestation occurred, were an issue. These false negatives were represented within Class O. In our findings, Class O is the most significant class because if the model predicts late blight too close to infestation, there is not enough time for the farmer to respond. A high rating for this section was therefore determined by a low Class O because it gives the farmers the best chance to prevent late blight:

- 5 - Class O is less than 10 % of outputs.
- 4 - Class O is more than 10 % but less than 20 % of outputs.
- 3 - Class O is more than 20 % but less than 30 % of outputs.
- 2 - Class O is more than 30 % but less than 40 % of outputs.
- 1 - Class O is more than 40 % of outputs.

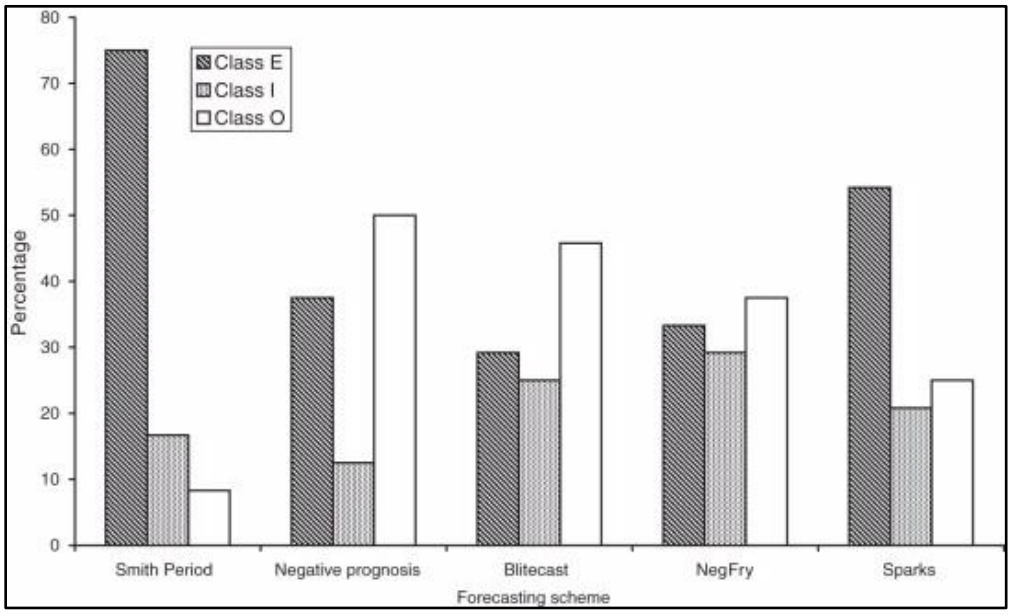

Figure 8: Reliability (Taylor et al., 2003)

Accuracy was another important factor in our decision matrix. In Taylor's research, accuracy is the difference between the optimal warning time, 10 days, and the model's average warning time as seen in Figure 9. Therefore, a high rating for this section was given to models with an average warning time closest to 10 days:

- 5 - Difference between average and 10 Day Warning is less than one day.
- 4 - Difference between average and 10 Day Warning is more than one day but less than three days.
- 3 - Difference between average and 10 Day Warning is more than three day but less than five days.
- 2 - Difference between average and 10 Day Warning is more than five day but less than ten days.
- 1 - Difference between average and 10 Day Warning is more than ten days.

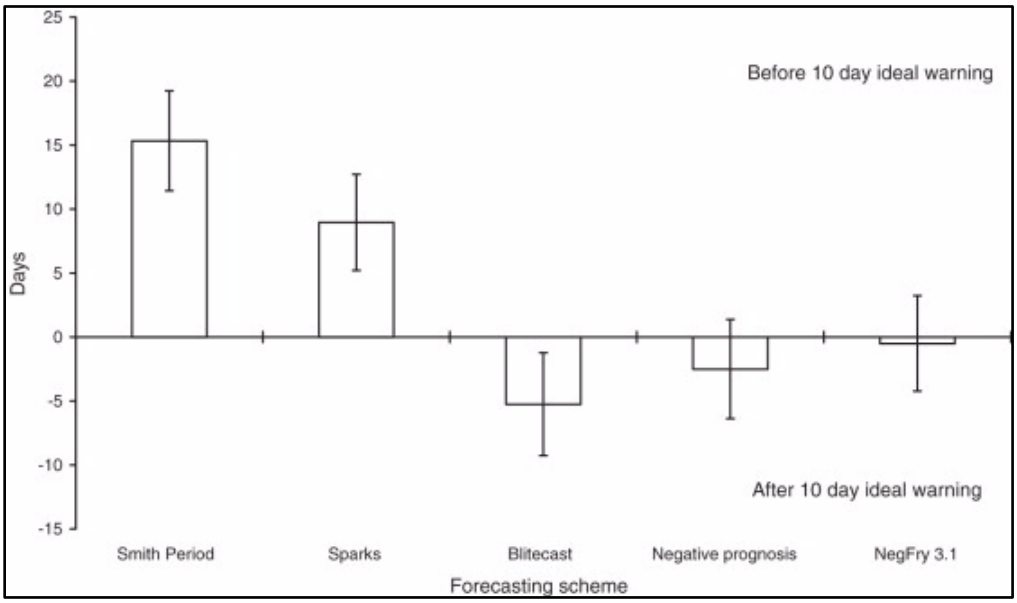

Figure 9: Accuracy (Taylor et al., 2003)

Past validity and the implementation was a factor because if the model was used in a region similar to Notia, fewer adaptations would be needed. The models were divided into groups based on their proximity to Greece, as seen in Table 1:

- 5 - Model has been validated or implemented in Greece
- 4 - Model has been validated or implemented in the Mediterranean region
- 3 - Model has been validated or implemented in Europe
- 2 - Model has been validated or implemented outside Europe
- 1 - Model has not been validated or implemented

Table 1: Implementation and Validity of Models (Bloom et al., 2014; Jones, 2013)

	Validated	Implemented
Blitecast	Eastern United States	United States
Smith Model	UK	UK
Negative Prognosis	Germany	Europe
Sparks	None	None
Negfry	Denmark, Norway, Sweden, and California	Europe

The last factor was the feasibility of the model. The feasibility was determined based on how much information was available about the calculations behind the model. If the calculations were explained thoroughly, it was possible for us to create an Excel program; however, if they were vague or not found, it would be impossible for us to complete the program. A high feasibility was also determined based on how difficult the calculations would be to formulate in Excel. We rated the feasibilities of the five models using the following scale:

- 5 - Very feasible: have all the resources to develop this model
- 4 - Feasible: could program but would have slight challenges
- 3 - Fairly feasible: could program but would have a number of challenges
- 2 - Possibly feasible: could program but would have an extreme number of challenges
- 1 - Not feasible: do not have the resources to develop this model

The Smith Period model proved to be most reliable and feasible for analyzing Notia's weather data to predict the first instance of late blight.

After rating each of the models, the Smith Period model was proven to be the most helpful for the farmers in Notia, earning 40 out of the possible 50 points, as seen in Table 2. More specifically, the Smith Period model was the most reliable, feasible, and validated and implemented in Europe, giving it the best chance for success. In terms of reliability, the Smith Period model consistently gave the farmers a blight warning far enough in advance for the farmer could take preventative measures. The Smith Model had a low accuracy because it predicted blight before the ideal 10 day window, however, it was more important that the farmers were ensured a warning with enough time to react. The Smith Period model was also chosen because it had been implemented in Europe, creating a higher probability the calculations could be used for the weather conditions in Notia. Finally, this model was most feasible because there was enough information about the calculations behind the model in order for us to create an Excel program.

Table 2: Decision Matrix for Determining Which Model is Best for Notia

Late Blight Predicting Models	Reliability	x 4	Accuracy	x 2	Validity and Implementation	x 1	Feasibility	x 3	Total Score out of 50
Blitecast	1	**4**	2	**4**	2	**2**	4	**12**	22
Smith Model	5	**20**	1	**2**	3	**3**	5	**15**	**40**
Negative Prognosis	1	**4**	3	**6**	3	**3**	3	**9**	22
Sparks	3	**12**	2	**4**	1	**1**	1	**3**	20
NegFry	2	**8**	5	**10**	3	**3**	2	**6**	27

The Smith Period Excel Program (SPEP) was developed as seen in Appendix E. SPEP predicts the first instance of late blight for the potato cultivar using the weather data from Notia as an input. After entering the hourly weather data into the Excel program, the user enters the sprouting date of the potato. The program examines each hour of the weather data after the sprouting date for certain relative humidity (RH) and temperature conditions. When analyzing the data, it keeps track of the number of hours within a 48 hour time span where the RH was 90% or more (Bloom et al., 2014). However, if the temperature during the 48 hours drops below 10 degrees Celsius, there is no longer a risk of blight, meaning the model discounts the previous data (Bloom et al., 2014). The model continues to run through the data, and if the SPEP finds a 48 hour time span where the temperature does not go below 10 degrees Celsius and the RH is 90% or more for 22 hours, the program recognizes there is a high probability blight will occur and recommends farmers to spray fungicides (Bloom et al., 2014).

The Smith Period model could help Notia farmers' reduce fungicide applications if the farmers switch from their traditional methods.

Currently the farmers in Notia use a traditional European fungicide regiment, where they begin to spray their fields when the potato plant grows to a height of 15cm, and continue to spray every 14 days (Duval, 1998). This method often results in an unnecessary amount of sprays before late blight would actually occur (Duval, 1998). However, using the Smith Period model can reduce the amount of these unnecessary sprays by predicting the first occurrence of late blight using weather data (Bloom et al., 2014). Specifically in England, the Smith Period model reduced the amount of unnecessary fungicide applications by three to five sprays compared to the traditional fungicide management (Hims, Taylor, Leach, Bradshaw, & Hardwick, 1995). If this model can be implemented in Notia, it has the potential to reduce the amount of fungicides by 33%, saving the farmers money on inputs, as well as improving the quality of their soil (A. Gertsis, personal communication, April 21, 2016).

4.3 Understand the Social Dynamics of Implementing Smart Agriculture in Notia

To establish strong social capital, it is vital to have program collaborators to whom the Notia farmers can relate.

Social capital is the cooperation between parties to achieve mutual goals, establishing trust within relationships and providing the groundwork for forming quality social interactions (Koutsou et al., 2014). For rural communities, trust in local entities and government institutions is a factor for success in innovation and implementation of initiatives (Koutsou et al., 2014). In Notia, the relationship between farmers and the collaborators is new and unproven with considerable uncertainty among the farmers about the benefits of smart agriculture practices. Trust has yet to be earned. A study of 110 farmers under 40 years old rated institutions on a 1-5 scale for their level of trust, with 1 being "total lack of trust" and 5 being "complete trust" (Koutsou et al., 2014). As it can be seen in Figure 10, the farmers have great trust in their friends and families with about 91% giving high to very high scores. But when it comes to public services, like the SPE and McCain, about 41% said they had absolutely no trust and less than 10% said they had high to very high trust. This goes to show that the relationships that farmers foster with outside collaborators should strive to mimic the relationships farmers have with their friends.

Major factors that played into the levels of trust between the farmers and collaborators is the fact that McCain's liaison was an agronomist, not a farmer, and a young female (K. Zoukidis, personal communication, April 1, 2016). Many of the farmers could not truly relate with the liaison, Martha, because of these differences between them. Since Martha was not a farmer, the Notia farmers did not always trust her expertise on field work, despite her education. The unwillingness and lack of trust displayed make it seem that McCain did not take the social capital of Notia into consideration when developing this program.

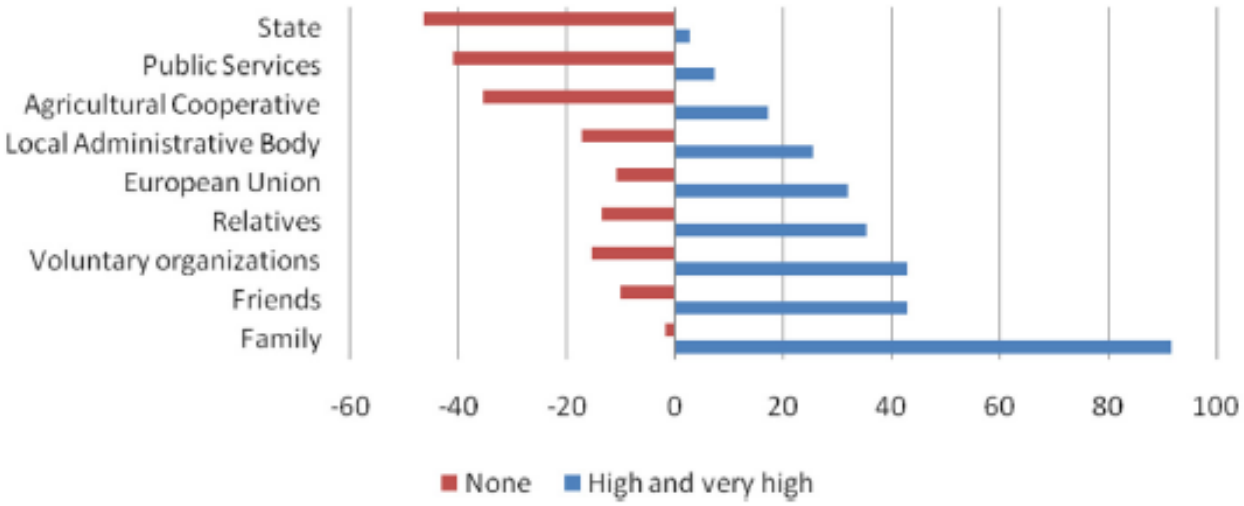

Figure 10: Farmers' trust levels (%) in individuals and institutions (Koutsou et al., 2014)

Figure 11: Interview with Farmer 7

The farmers were reluctant to change their potato cultivation practices during the first year of the program since there was no evidence from prior field testing that the Servane cultivar would be successful in Notia.

No testing of the Servane cultivar was performed in Notia prior to McCain signing contracts with the farmers. To prevent complications when introducing new crops, researchers test cultivars in a variety of soil conditions over multiple growing seasons (Mori et al., 2015). Since the McCain program did not perform any local testing of the cultivar, there was uncertainty the yields and quality would improve compared to the farmers' past cultivars in Notia's conditions (E. Vergos, personal communication, April 12, 2016).

There is already a hesitation among the farmers to change their practices, and changing it to a protocol that isn't fully developed to the area can lead to more hesitation. The unwillingness of the farmers lead to only 12%, 3 out of 25 farmers, completely following the protocol in its first year (E. Vergos, personal communication, April 12, 2016). A farmer in the program expressed concern, saying, "I changed my cultivation methods ever since I became part of the group [program]. I had good results, but I'm not convinced it is working because it has only been one year" (Farmer 7, translated). Most of the farmers interviewed stated that there was no evidence that this particular cultivar was saving the farmers money, giving them more yield, or creating a sustainable production process. Fully implementing changes in their farming practices takes many years, so it is understandable that these farmers were hesitant to change their tuber variety.

At times, farmers would substitute cheaper inputs in place of required, higher quality inputs specified in the protocol.

One goal of the program was to motivate farmers to reduce the amount of inputs, such as fertilizers, through trainings on the protocol. As part of this effort, McCain provided the tuber seeds at a reduced price to the farmers but required them to purchase fertilizer that was more expensive than the brand they used in the past. Many farmers were reluctant to spend the extra money on the fertilizer required in the protocol since there was no evidence that this new fertilizer would perform better than their traditional fertilizer. Instead some farmers continued to buy from their long-standing supplier who sold fertilizer manufactured in Bulgaria. One farmer continued to use the Bulgarian fertilizer on his land, but by the time harvesting came around, he had no usable potato crop (E. Vergos, personal communication, March 15, 2016). The resistance from some of the farmers to use the new fertilizer caused tensions between the farmers, the SPE and McCain.

Age and experience are not the only factors which caused farmers to be less willing to change their practices.

Past research has proven that age is a factor when trying to implement new farming practices since experienced, older farmers have been less willing to adopt new methods (Oxouzi & Papanagiotou, 2010). However, the farmers in Notia have shown that age is not the only factor. Seven out of the nineteen farmers who signed up for the second year of the McCain program spoke with us. Of those farmers, six were at least 40 years old. As it can be seen in Figure 12, one of the six farmers had 20 or more years of experience and followed the protocol. In previous research, this farmer would be considered an outlier because he contradicts the pattern that older farmers are less willing to adopt new practices. This contradiction was emphasized by the fact that there were younger farmers with less experience who did not follow the protocol. This "outlier" goes to show that there must have been other factors, including a lack of social capital, prior results, and collaborators who were relatable to the farmers, which inhibited the remaining four experienced farmers from changing their practices.

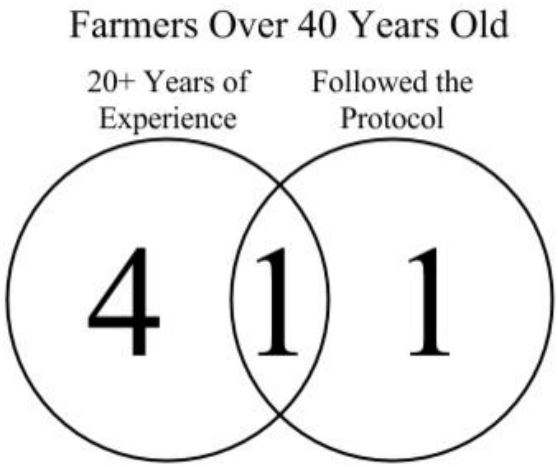

Figure 12: Venn Diagram of the interviewed farmers who were at least 40 years old

4.4 Limitations

We originally intended to conduct lengthy field investigations and in-depth interviews with the farmers so that we could get to know them and better understand their experience with the McCain program. However, this ethnographic research was not possible. The farmers had little time to spare as they were getting ready to prepare their fields and plant their seed potatoes. In addition, the language barrier was more formidable than anticipated since few farmers spoke English and we had limited access to translators. In broader terms, the tensions between the farmers and among different groups formed in the first year, meant many farmers did not want to talk with us. Therefore, we only had the opportunity to be in contact with them through two training sessions, giving us only enough time to conduct interviews. Even these interviews were challenging since the farmers who came to the training session refused to speak with us at first. We attribute this hesitation to them not fully understanding who we were or what we were hoping to accomplish.

Chapter 5: Recommendations

The following recommendations can help spur innovation in farming practices and further the use of smart agriculture techniques in communities like Notia:

1. Verify Smith Period Excel Program (SPEP) with weather data and test plots, before use in Notia.
2. Test cultivars prior to full production for future CSR's or extension services.
3. Utilize effective ways to communicate and collaborate with farmers.
4. When teaching new practices, use methods that are relevant and visually engaging to the farmers.

First, we recommend that the SPE validate the Smith Period Excel Program (SPEP) that we created, as seen in Appendix E, for use in Notia and compare it against the model that McCain may provide to the SPE. Research suggests the Smith Period model would result in less sprays than conventional methods, but that needs to be verified in field testing done by the SPE (Bloom et al., 2014). These tests will also verify the reliability of the model in Notia. To validate the model for Notia, tests should be conducted over one or more growing seasons (Bloom et al., 2014). These tests should be conducted with multiple, small test plots of the Servane cultivar without the use of fungicides in Notia. During the tests, the date that the model outputs for late blight will be validated if late blight occurs after that warning. Once the SPEP model has been verified, it can be fully implemented into the farmers' practices.

Second, we recommend that new cultivars are tested prior to their use in corporate social responsibility projects or those promoted by extension services. Testing cultivars will determine the performance and resistance to diseases of the new crop and then, if the cultivar is successful, it can be implemented in commercial production (Gisselquist & Srivastava, 1997). One method of testing new cultivars is through on-farm testing. The cultivar will undergo field trials of a variety of treatments to see how the crop will react to those tests in the region's environment and conditions (Guy, Miller, Smith, & Wuest, 1995). These tests will help determine if the new farming techniques will be viable in the area and produce a successful crop (Guy et. al., 1995).

Third, opportunities exist to enhance communication and collaboration between the SPE and rural farmers. The SPE communicates with Notia farmers via face to face contact or through the liaison. However, the SPE could send text messages to the farmers to inform them of pest and disease outbreaks, including the probability of late blight. (Mittal & Parthasarathy, 2013). For example, the cellular service, Vodafone, established the Vodafone Farmers' Club in Turkey where farmers receive SMS texts about local weather forecasts and assistance for pest control and resource management (Vodafone Group, 2014). This has led to an estimated savings of $140 million, or about €125 million, among 790,000 farmers (Vodafone Group, 2014). Coupled with effective communication, collaboration between the SPE and the farmers is vital. A study conducted in the Pella prefecture of Northern Greece found that when teaching farmers, it is important to harness collaboration (Chalikias, Kalaitidis, Karasavvidis, & Pechlivanis, 2010). Promoting teamwork and common understanding could shape new ways of thinking and a positive mentality to shift from traditional farming methods to smart agriculture practices (Chalikias et. al., 2010). This could be feasible in Notia by creating a strong social capital, which will then allow for opportunities to foster participation among the farmers (Koutsou et al., 2014).

Lastly, when teaching new farming practices it is important to have relevant and visually

engaging teaching methods. In the Pella study, farmers requested to have relevant training programs which would ensure adequate skills in developing more sustainable practices (Chalikias et. al., 2010). Trainings should also be organized in ways where practical demonstrations are available, giving the farmers opportunities to engage in the testing of smart agriculture strategies (Reichardt & Jürgens, 2009). When presenting, the educator should create opportunities for participation among the farmers, which could make it easier for them to adopt new practices (Chalikias et. al., 2010). With participation and engaging presentations, the farmers will be able to connect the theory and practice of using smart agriculture (Chalikias et. al., 2010).

Chapter 6: Conclusion

Utilizing efficient and sustainable smart agriculture practices can improve the quantity and quality of crops, which ultimately improves the livelihood of farmers. The benefits associated with adopting new methods to reduce the amount of inputs and effects on the environment can improve rural livelihoods, especially those living in impoverished areas (Van Hooijdonk, 2015).

In the case study with Kilatzidis, we noticed that it was vital to dedicate time and space to testing a new cultivar instead of bringing it straight to large-scale production. In Notia, the farming of the Servane cultivar was an experiment in its own right. Without multi-year field tests of the Servane variety, or a protocol adapted and tested for conditions in Notia, local farmers were understandably resistant to demands for changes in potato cultivation practices. If Notia farmers had evidence that the Servane variety could grow well in the area, they might have been more willing to adjust their farming practices.

The first year of the McCain program had many setbacks while trying to implement smart agriculture practices. Many farmers did not follow the protocol to grow the Servane potato due to the economic, historic, political, and social complexities discussed in this report. In order for the SPE to foster participation in the second year of the program, there are steps that could encourage farmers to adopt these practices. The Smith Period Excel Program (SPEP) needs to be validated for Notia's weather conditions to show the farmers the program works before it is implemented as a smart agriculture practice. The information should also be presented through visually engaging and relevant teaching material, as well as through direct communication between collaborators and the farmers in order to foster more trust. Through these steps, it is possible for smart agriculture to be implemented, however, it is a process that cannot be rushed.

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Appendix A: Interview Questions for Case Study with Savvas Kilatzidis

Consent Statement: *Hello, my name is _____. I am a student at Worcester Polytechnic Institute. I am collecting information to help the School of Professional Education utilize telemetric data in farming practices. Would you be willing to answer a few questions and allow us to record the information?*

1. What is an average day like for you?
    a. How many hours do you spend on your farm?
2. Who helps you out on your farm?
    a. How many people?
3. How long has your family been farming?
    a. Did you inherit the farm from your family?
4. How much did your family teach you?
    a. Did they keep logs/notes or just use techniques that are past down from generations (i.e. from your father)
5. Did anything you get taught at the American Farm School go against what your family used to practice in farming or was it significantly different?
6. Have you experienced any specific challenges with using precision agriculture? If so, could you describe one?
7. What has your experience been like while you've been using this information/technology?
    a. What is your favorite part/aspect of using these technologies?
    b. What is your least favorite part/aspect of using these technologies?
    c. Would you recommend these practices to other farmers? Why?
8. What difficulties have you faced in the past such diseases, not enough yield, variability?
9. Have you seen a drastic change in the yield of your crops?
    a. Was it a beneficial changes?
    b. How much did they change?

Appendix B: Interview Questions for Key Informants

Consent Statement: *Hello, my name is _____. I am a student at Worcester Polytechnic Institute. I am collecting information to help the School of Professional Education utilize telemetric data in farming practices. Would you be willing to answer a few questions and allow us to record the information?*

Dr. Evangelos Vergos's Questions

Understanding the Program

1. Please explain the program, what its intentions are, and the approaches it uses?
    a. Please explain your part in the program?
    b. What is your relationship with the farmers?
    c. What is your end goal for each farmer?
2. Do you believe there are other technological strategies that might result in greater engagement by farmers?

Willingness of Farmers to Adopt New Practices

3. How unwilling do the farmers need to be in order to get kicked out of the program?
4. Why do some farmers see the value of using information technologies in their cultivation practices while others do not?
5. Have you worked on a similar program where precision agriculture was integrated into their farming practices?
    a. Was there any resistance in the beginning?
    b. Did the farmers end up changing their practices?
    c. How long did this program/initiative take?
    d. How did they react to the integration of precision agriculture?

Integration of Technology/Methods

6. In the adult education classes, we noticed there was a precision agriculture course.
    a. What age group has signed up for these classes?
    b. Is there any resistance or obstacles to adopt the practices that are taught in the class?

Dr. Athanasios Gertsis's Questions

Understanding the Program

1. Please explain the program, what its intentions are, and the approaches it uses?
    a. Please explain your part in the program
    b. What is your relationship with the farmers?
2. Is there any specific criteria for selecting farmers to participate in this program?

Integration of Technology/Methods

3. What are your opinions on using weather data to direct farming strategies?
4. How would the information from McCain's model be communicated to the farmers?
    a. Through informational meetings, mail, email, text?
5. Will you use alternative models to provide additional information along with what McCain provides? Also, will you compare other models' information to McCain's?
6. Can you think of other strategies that have not yet been attempted that might result in greater engagement by farmers?

Willingness of Farmers to Adopt New Practices

7. Please explain your view on the willingness of Notia farmers to adopt new practices in the McCain program?
8. Have you noticed a change in practices or a willingness to change their practices?
9. Are the farmers using the required (contractual?) practices only on their McCain plots or on all of their fields?
10. What suggestions have been made to the farmers thus far in the program?
11. How have they responded to those suggestions?
12. Since the farmers have requested more weather stations, what do they hope to use them for?

Konstantinos Zoukidis's Questions

Understanding the Program

1. Please explain the program, what its intentions are, and the approaches it uses?
    a. Please explain your part in the program
    b. What is your relationship with the farmers?
2. Is there any specific criteria for selecting farmers to participate in this program?

Willingness of Farmers to Adopt New Practices

3. Please explain your view on the willingness of Notia farmers to adopt new practices in the McCain program?
    a. Why do you think this is true?
4. Have you noticed a change in practices or a willingness to change their practices?
5. Do you notice any of the farmers using the required practices on their other plots?
   [Are the farmers using the required (contractual?) practices only on their McCain plots or on all of their fields?]
6. What suggestions have been made to the farmers thus far in the program?
7. How have they responded to those suggestions?

Integration of Technology/Methods

8. How often do most of the farmers spray fungicides on the crop?
    a. When do most of the farmers first spray fungicides on the crop?
    b. Do they have a set time interval that they spray each new application of fungicide throughout the season?
9. What is your opinion on using weather and soil data to direct farming strategies?
10. What communication methods do you use to provide suggestions?
11. Do you believe there are other technological strategies that might result in greater engagement by farmers?
12. Have you seen farmers discussing their observations between each other or suggesting methods?

Anna Papakonstantinou's Questions

Understanding the Program

1. Please explain the program, what its intentions are, and the approaches it uses?
    a. Please explain your part in the program?
        i. How have you been involved in the program?
    b. What is your relationship with the farmers?
2. Is there any specific criteria for selecting farmers to participate in this program?
3. Do you have any past experience working with farmers, such as those in Notia?
    a. Were you able to give them suggestions to help with their current farming methods?
    b. How did they respond?

Integration of Technology/Methods

4. What is your opinion on using weather and soil data to direct farming strategies?
5. What communication methods **would** you use to provide suggestions?
6. Do you believe there are other technological strategies that might result in greater engagement by farmers?
7. As an agronomist, what conditions do you look for when analyzing soil samples?
    a. Have you reviewed any of the soil analysis results from Notia?

Appendix C: Interview Questions for Farmers (English and Greek)

Consent Statement: *Hello, my name is _____. I am a student at Worcester Polytechnic Institute. I am collecting information to help the School of Professional Education utilize telemetric data in farming practices. Would you be willing to answer a few questions and allow us to record the information?*

1. How long have you been farming?
2. What farming procedures do you see as most important and why?
3. How do you assess/anticipate weather patterns?
    a. Do you make adjustments in strategies based on weather conditions? If so, what steps do you take when various weather events occur, such as a great amount of rain or a drought?
4. Would you be willing to make small adjustments to your farming routines based on weather patterns if it meant an increase in marketable production?
5. How would you describe your relationship with the SPE?
6. How do you get your information about what strategies to try?
    a. Do you use techniques that other farmers in this region/country/the world don't use? Can you explain?
    b. Do you discuss strategies and approaches with farmers nearby?
7. What farming techniques did you use before the program?
    a. Which of these haven't changed?
    b. Prior to the program, did you change or think about changing your farming practices in any way?
    c. If farming was passed down in your family, how did earlier generations plant potatoes?
8. How is growing the Servane cultivar different from growing other varieties?
9. What problems have you faced with your potato crop in the past few years?
10. How do you make decisions about when you apply fungicides (or fertilizer, etc)?

ΣΧΟΛΗ ΕΠΑΓΓΕΛΜΑΤΙΚΗΣ ΕΚΠΑΙΔΕΥΣΗΣ

Συνέντευξη με συμβολαιακούς πατατοπαραγωγούς της
εταιρείας McCain Hellas

Δήλωση συναίνεσης: Χαίρετε! Τ' όνομά μου είναι …… και είμαι φοιτητής της Σχολής Μηχανολόγων Μηχανικών, του WPI των ΗΠΑ. Βρίσκομαι στην Ελλάδα ως φοιτητής ανταλλαγής με την Αμερικανική Γεωργική Σχολή κι εργάζομαι σ' ένα project που αφορά την καινοτομία στον αγροδιατροφικό τομέα. Για την επιτυχή έκβαση της εργασίας μου, συλλέγω πληροφορίες για τις εφαρμογές της τηλεμετρίας και τη χρησιμότητα των μετεωρολογικών δεδομένων στην πρωτογενή γεωργική παραγωγή. Για το λόγο αυτό, θα θέλατε ν' απαντήσετε στο παρακάτω ερωτηματολόγιο?

ΕΡΩΤΗΣΕΙΣ

1. Πόσα χρόνια ασκείται το επάγγελμα του γεωργού?
2. Ποιες καλλιεργητικές εργασίες θεωρείτε πιο σημαντικές και γιατί?
3. Με ποιον τρόπο εκτιμάτε, ή προβλέπετε τα καιρικά φαινόμενα?
    a. Πως προσαρμόζεται τις καλλιεργητικές φροντίδες στις καιρικές συνθήκες, και κυρίως σε φαινόμενα, όπως η υπερβολική ποσότητα βροχής, ή ξηρασία σε σχέση με την παραγωγή?
4. Θα ήσασταν διατεθειμένος να κάνετε μικρές προσαρμογές (ή αλλαγές) στις συνήθεις καλλιεργητικές σας πρακτικές, με βάση τα καιρικά φαινόμενα, αν αυτό θα σήμαινε αύξηση της εμπορεύσιμης παραγωγής?
5. Πώς περιγράφετε τη σχέση σας με την Αμερικανική Γεωργική Σχολή και τις υπηρεσίες που σας προσφέρει?
6. Ποια είναι η πηγή των πληροφοριών σας σχετικά με τις στρατηγικές καλλιέργειας που χρησιμοποιείτε?
    a. Χρησιμοποιείτε τεχνικές που δεν χρησιμοποιούν άλλοι αγρότες στην περιοχή σας/στη χώρα σας/ για την ίδια παραγωγή προϊόντος? Παρακαλώ εξηγείστε.
    b. Οι αγρότες στην περιοχή σας κάνουν συναντήσεις για να συζητήσουν τις στρατηγικές και τις προσεγγίσεις που θα ακολουθήσουν?
7. Τι είδους καλλιεργητικές τεχνικές χρησιμοποιούσατε πριν την έναρξη και συμμετοχή σας στο πρόγραμμα?
    a. Ποιες από αυτές δεν αλλάξατε?
    b. Σκοπεύατε να αλλάξετε, ή είχατε σκεφτεί να αλλάξετε με κάποιον τρόπο τις γεωργικές πρακτικές σας πριν τη διεξαγωγή του προγράμματος?
    c. Αν προέρχεστε από αγροτική οικογένεια, οι προηγούμενες γενιές καλλιεργούσαν πατάτα;
8. Πως μεγαλωνει η Servane πατατα σε διαφορα απο τις αλλες ποικιλιες;
9. Τι προβληματα εχετε αντιμετωπισει με την ποικιλια της πατατας τα προηγουμενα χρονια;
10. Πως περνεται αποφαση για το αν θα χρησημοποιησεται μυκητοκτονα (η λιπασματα κ.λ.π.);

Appendix D: The Case of Savvas Kilatzidis

After only one year of attending Perrotis College, Savvas Kilatzidis was already applying the knowledge from his studies. During his breaks, he would talk to his father about what he has learned, and at one point, he recommended adding crop rotations into the current cultivation process on the farm. Upon graduating in 2011 with a degree in Environmental Systems Management and a concentration in precision agriculture, he began to manage his father's 1000 hectare farm which cultivated corn, wheat, and other soft cereals in Drama, Greece. Now at the age of 26, Kilatzidis has created a series of changes to the farming business his father created 35 years ago.

Beginning his agricultural adventure with a suggestion in crop rotation, Kilatzidis has since advanced his farm by implementing new technology and different cultivation options. With his changes, the business was able to expand its exports from Greece and Italy to places all over the world including Germany, United States, Cyprus, and Switzerland. When Kilatzidis decided to grow his family's business into more international markets, he knew that changes were needed in order to stay competitive. One example of this is when he made 600 hectares of the farmland organic. His reason for doing this was so that he would be competitive in foreign markets, especially the US market.

Kilatzidis also implemented new machinery and cultivars into his farming practices to stay competitive in foreign markets. For example, his newest tractor, which cost €300,000, has the ability to drive itself through the fields using GPS. The new tractor finds the most efficient route through the fields, which saves Kilatzidis time and fuel. Kilatzidis learned how to use this precision agriculture technology by reading a manual about it on the internet and then taught himself since the company did not come out and demonstrate how to use it. In addition to the new tractor, Kilatzidis bought a spraying machine that lays down an even layer of fertilizer, regardless of the tractor's speed. Using this machine reduces the amount of excess fertilizer, thereby saving him money. Initially, it cost more to get the equipment, but after a few seasons he earned the money back and more. Additionally, he received a 60% subsidy from the Europeans Union's CAP payments to purchase the new tractor because it replaced an old one.

Kilatzidis also constantly tests for new cultivars that could result in greater yield than the crop he currently grows. He finds these new cultivars through research on the internet. Each cultivar is tested for at least two years in approximately 20 to 50 hectares of land with various soil types. The cultivars are expected to produce a certain amount of yield, however, Kilatzidis found these yields were only possible under highly optimal conditions and not accurate to his production. Only about one in ten of the new cultivars Kilatzidis tests end up being better than his main crops, but he says that the one crop is worth it since it can be highly lucrative. Utilizing these tactics has enabled Kilatzidis to grow his family's farm and continue to be competitive in the agricultural market.

Although Kilatzidis has been very successful with his farm, he continues to face the challenge of implementing precision agriculture techniques. Of the fourteen farmers he employs, eight of them refuse to drive his automated tractor. The older workers did not want to damage the expensive equipment and did not trust the new technology. Kilatzidis said, "they used to drive the machines with no hydraulics, nothing, everything is on their hands and legs. They cannot trust now the machines." The older workers will continue to use the older tractors while the younger workers use the new ones. Even though Kilatzidis is advancing his farm's technology, his older workers are not fearful that the new tractors will put them out of a job. In regards

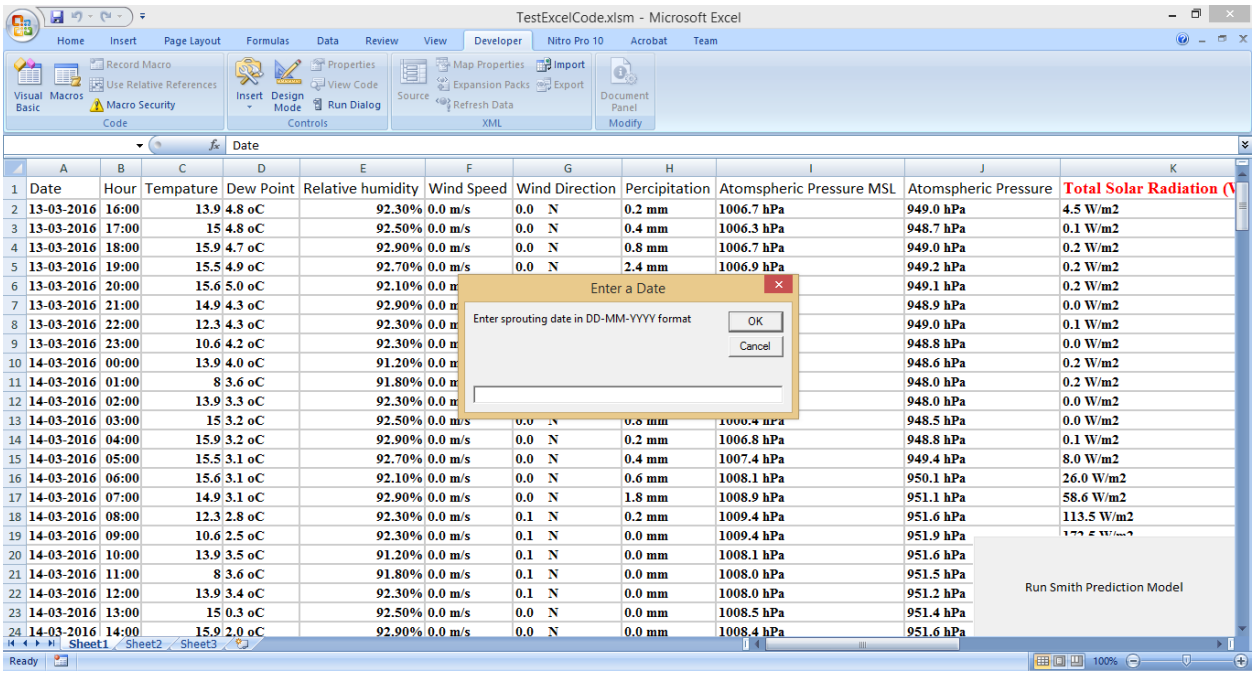
to all workers, the self-driving tractor cannot replace them since it is illegal to have a tractor driving without someone inside monitoring it.

Kilatzidis's father, who is retired from farming, also does not trust the tractor because he believes it may lock up or malfunction. Kilatzidis has explained to him how beneficial it is in hopes that the advantages of it will alter his uneasiness towards using it. He gave the statistic that it only uses 292 liters of fuel when driving itself in comparison to a human driving it who would use 300 liters. It has also saved him 72 metric tons of fertilizer. Even with numbers showing how beneficial this machine is, his father "will say, 'yes, it's okay, but I will not try it.'"

While Kilatzidis is highly knowledgeable about the technology on his farm, he recognizes the challenges when training his older workers to use new machinery. For the older farmers, it takes a lot more time for them to understand the concepts and feel comfortable with this technology. Kilatzidis found it too difficult and time consuming to give extensive training sessions where he would show precisely how to work the machines to those who are reluctant to learn. For that reason, in Kilatzidis's view, it is more beneficial to hire younger farmers because they can adjust faster. His difficulty in trying to teach older farmers has shown us the tensions that lie between new technology and older farmers.

Appendix E: Smith Period Excel Program

The Smith Period Excel Program (SPEP) is used to predict the first occurrence of blight in the fields so that farmers may spray fungicides. SPEP based off the Smith Period that was created by Smith (Bloom et al., 2014). To begin the program, input data from the weather station. Not all of the columns are necessary - only the date, time, temperature, and relative humidity (RH) - but the program was set up for the easiest possible use as this is the format which the information comes from the weather station. It is essential to make sure that there are no units included with the numbers in the temperature column and that the RH is in decimals from 1.00 to 0.00. Once the data is in the Excel spreadsheet, press the button at the bottom right corner which reads "Run Smith Prediction Model". This layout can be seen in Figure 13 below.



Date	Hour	Tempature	Dew Point	Relative humidity	Wind Speed	Wind Direction	Percipitation	Atomspheric Pressure MSL	Atomspheric Pressure	Total Solar Radiation (V
13-03-2016	16:00	13.9	4.8 oC	92.30%	0.0 m/s	0.0 N	0.2 mm	1006.7 hPa	949.0 hPa	4.5 W/m2
13-03-2016	17:00	15	4.8 oC	92.50%	0.0 m/s	0.0 N	0.4 mm	1006.3 hPa	948.7 hPa	0.1 W/m2
13-03-2016	18:00	15.9	4.7 oC	92.90%	0.0 m/s	0.0 N	0.8 mm	1006.7 hPa	949.0 hPa	0.2 W/m2
13-03-2016	19:00	15.5	4.9 oC	92.70%	0.0 m/s	0.0 N	2.4 mm	1006.9 hPa	949.2 hPa	0.2 W/m2
13-03-2016	20:00	15.6	5.0 oC	92.10%	0.0 m				949.1 hPa	0.2 W/m2
13-03-2016	21:00	14.9	4.3 oC	92.90%	0.0 m				948.9 hPa	0.0 W/m2
13-03-2016	22:00	12.3	4.3 oC	92.30%	0.0 m				949.0 hPa	0.1 W/m2
13-03-2016	23:00	10.6	4.2 oC	92.30%	0.0 m				948.8 hPa	0.0 W/m2
14-03-2016	00:00	13.9	4.0 oC	91.20%	0.0 m				948.6 hPa	0.2 W/m2
14-03-2016	01:00	8	3.6 oC	91.80%	0.0 m				948.0 hPa	0.2 W/m2
14-03-2016	02:00	13.9	3.3 oC	92.30%	0.0 m				948.0 hPa	0.0 W/m2
14-03-2016	03:00	15	3.2 oC	92.50%	0.0 m/s	0.0 N	0.8 mm	1006.4 hPa	948.5 hPa	0.0 W/m2
14-03-2016	04:00	15.9	3.2 oC	92.90%	0.0 m/s	0.0 N	0.2 mm	1006.8 hPa	948.8 hPa	0.1 W/m2
14-03-2016	05:00	15.5	3.1 oC	92.70%	0.0 m/s	0.0 N	0.4 mm	1007.4 hPa	949.4 hPa	8.0 W/m2
14-03-2016	06:00	15.6	3.1 oC	92.10%	0.0 m/s	0.0 N	0.6 mm	1008.1 hPa	950.1 hPa	26.0 W/m2
14-03-2016	07:00	14.9	3.1 oC	92.90%	0.0 m/s	0.0 N	1.8 mm	1008.9 hPa	951.1 hPa	58.6 W/m2
14-03-2016	08:00	12.3	2.8 oC	92.30%	0.0 m/s	0.1 N	0.2 mm	1009.4 hPa	951.6 hPa	113.5 W/m2
14-03-2016	09:00	10.6	2.5 oC	92.30%	0.0 m/s	0.1 N	0.0 mm	1009.4 hPa	951.9 hPa	
14-03-2016	10:00	13.9	3.5 oC	91.20%	0.0 m/s	0.1 N	0.0 mm	1008.1 hPa	951.6 hPa	
14-03-2016	11:00	8	3.6 oC	91.80%	0.0 m/s	0.1 N	0.0 mm	1008.0 hPa	951.5 hPa	
14-03-2016	12:00	13.9	3.4 oC	92.30%	0.0 m/s	0.1 N	0.0 mm	1008.0 hPa	951.2 hPa	
14-03-2016	13:00	15	0.3 oC	92.50%	0.0 m/s	0.0 N	0.0 mm	1008.5 hPa	951.4 hPa	
14-03-2016	14:00	15.9	2.0 oC	92.90%	0.0 m/s	0.0 N	0.0 mm	1008.4 hPa	951.6 hPa	

Figure 13: Layout of the Smith Period Excel Program

Upon starting the program, a prompt will come up, seen in Figure 14, asking for the date at which the potatoes began sprouting. This allows the program to cut out any data from before that date which do not have any impact on the prediction of blight. This feature also makes it easier to use, allowing the user to copy previous data in without worrying about how the earlier data will affect the output. If a date is input that is not found in the spreadsheet, the program will output an error message, Figure 15, and exit.

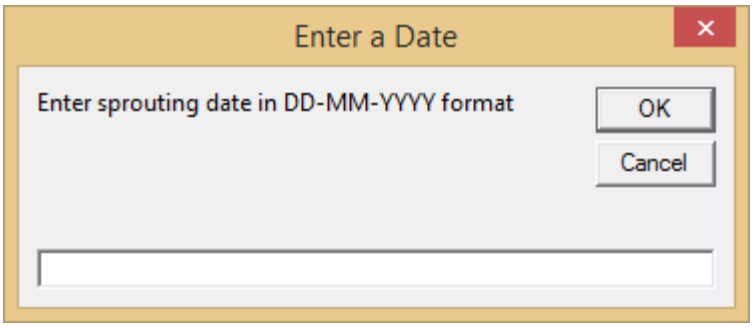


Figure 14: Date Prompt

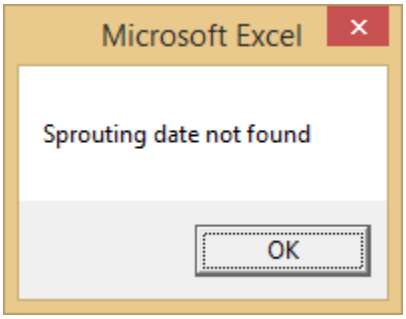


Figure 15: Error Message

After entering in the date, the program will determine whether or not blight is predicted and if the farmers should spray their fields. Figure 16 shows the two possible outputs from the program, the left being that blight was detected after a certain date, and the right being that no blight was detected.

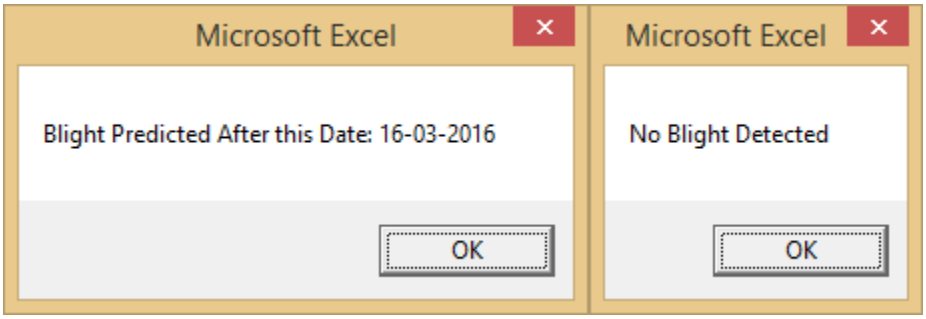


Figure 16: The SPEP output

```
Function findLastRow()
    ' Find empty row
    Dim rowNum As Integer
    rowNum = 2

    Do While True
        ' Check if Cell is empty
        If IsEmpty(Range("A" & rowNum).Value) Then
            Exit Do
        End If
        ' Otherwise increment rowNum
        rowNum = rowNum + 1
    Loop
    ' Subtract 1 from rowNum to get last filled row
    rowNum = rowNum - 1

    ' Return rowNum
    findLastRow = rowNum
    MsgBox "Last Row is " & rowNum
End Function
```

```
Function findStartingRow(startDate, lastRow)
    ' Find starting row
    Dim rowNum As Integer
    rowNum = 1

    Do While rowNum <= lastRow
        ' Check if date in cell is equal to startDate
        If InStr(1, Range("A" & rowNum).Text, startDate) Then
            Exit Do
        End If
        ' Otherwise increment rowNum
        rowNum = rowNum + 1
    Loop
    ' Check to see if date was ever found and return
    If rowNum > lastRow Then
        findStartingRow = 0 ' returns error
        Else ' returns correct row
            findStartingRow = rowNum
    End If
    MsgBox "Starting Row is " & findStartingRow
End Function
```

```
Function smithTest()
    ' set up variables
    Dim hrCount1 As Byte
    Dim hrCount2 As Byte
    hrCount1 = 0
    hrCount2 = 0
    Dim blightDate As String

    ' Input start date
    Dim startDate As String
    startDate = InputBox("Enter sprouting date in DD-MM-YYYY format ", "Enter a Date")
    If startDate = vbNullString Then
        MsgBox ("User Canceled")
        Exit Function
    End If

    ' Return number of data reads
    Dim lastRow As Integer
    lastRow = findLastRow()

    ' Search for starting row
    Dim startingRow As Integer
    startingRow = findStartingRow(startDate, lastRow)

    ' If findStartingRow through an error, returned 0, then start date was not found. Exit function
    If startingRow = 0 Then
        MsgBox "Sprouting date not found"
        Exit Function
    End If

    ' If lastRow - startingRow < 48, return "Model requires 2 days of data since planting" and exit
    If (lastRow - startingRow) < 48 Then
        MsgBox "Model requires 2 days of data since planting"

        Else
        ' From found row, start searching for 2 consecutive days
        ' where the minimum temp is 10 degrees Celsius and
        ' there is at least 11 hours of 90% humidity per day.
        ' Make while-loop which alters the bounds of the for-loop
        ' so that every time it drops down one hour and recalculates.
            ' While-loop start (while (lastRow - startingRow) >= 48)
            Do While (lastRow - startingRow) >= 47
                ' For-Loop start
                For i = startingRow To (startingRow + 47)
                    ' If less than 10 degrees celsius, clear hour count and break for-loop
                    If Range("C" & i).Value < 10 Then
                        hrCount1 = 0
                        hrCount2 = 0
                        Exit For
                    End If

                    ' If 90% humidity, increase hour count
                    If Range("E" & i).Value >= 0.9 Then
                        If i <= (startingRow + 23) Then
                            hrCount1 = hrCount1 + 1
                            Else
                                hrCount2 = hrCount2 + 1
                        End If
                    End If
                Next
                ' End for-loop

                ' if hour count > 10, return yes and the date. Break while-loop
                If hrCount1 > 10 And hrCount2 > 10 Then
                    blightDate = Range("A" & (startingRow + 48))
                    MsgBox "Blight Predicted After this " & "Date: " & blightDate & Chr(10)
                    Exit Do
                    ' else startingRow += 1
                    Else
                        startingRow = startingRow + 1
```

```
                        hrCount1 = 0
                        hrCount2 = 0
                    End If
                ' End while-loop
                Loop

        ' If lastRow - startingRow < 48, print No
        If (lastRow - startingRow) < 48 Then
            MsgBox "No Blight Detected"
        End If
    End If
End Function
```

Figure 17: Code for the SPEP