Hertie School

Precision Agriculture: Is There Really an App for That?

Evaluating Farmer Reviews of Agricultural Mobile Applications

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Executive Summary

Governments such as the European Union and the United States are starting to encourage the use of precision farming as a solution to the predicament their societies and the global community are facing to increase food production while reducing environmental degradation. Precision farming is an agricultural method that considers variability within fields and facilitates more precise crop treatments through enhanced monitoring and tracking. It is gaining popularity because it has the potential to increase yields while reducing inputs such as water, fertilizer, and pesticides. Research has shown that mobile apps might be a useful tool to aid farmers in using these smart agricultural techniques. So far, agricultural apps exist that help farmers manage their inventories and data, track rainfall, detect and diagnose plant diseases, obtain the most recent market trends, and more. There is a lack in research that examines what influence, if any, these apps have had on making farming more precise. Also, there is an absence of literature that examines how farmers view the apps or what features they find useful. This study aims to determine how precision farming can be successfully implemented through an app.

Agricultural app reviews were collected from the Google Play website and then analyzed using textual analysis techniques. Topic modeling, sentiment analysis, and manual reading found that the cost of an app as well as its usability often determined an app's success. The results also indicate that if a farmer already has a tool for a specific need, the app should enhance the convenience of performing the task and be relatively cheap. For more complicated technology, such as GPS field tracking and AI crop disease detection, farmers appreciate clear instructions and very high accuracy. Other various information was gathered from the same app review process and was discussed in detail. Further research is needed to identify more app features that are important to farmers using precision agriculture.

I. Introduction

Population growth, increasing standards of living, climate change, and health concerns are impacting and placing unprecedented demands on agricultural productions across the world. Farmers are tasked with increasing yields, reducing fertilizer and pesticide use, transitioning to organic production, and reducing food waste. The idea of using data and technologies for precision farming is gaining popularity because it has the potential to simultaneously address all these issues at once.

There are several hurdles that keep precision farming from integrating into normal agricultural practice. This includes issues such as expense, lack of exposure to new techniques, and perhaps a lack of encouragement. Therefore, some political bodies, such as the U.S Department of Agriculture (USDA) and the European Union (EU), are promoting the development of mobile applications (apps) which have the potential to be a convenient and inexpensive way for farmers to start incorporating efficient techniques into their work ("*New and Innovate Mobile Apps Help Farming to Get Smarter*", 2017). Studies conducted to determine how willing farmers would be to use phone apps to aid in precision farming show promise (Abdullahi et al., 2021; Jaafar & Kharroubi, 2021). There seems to be few studies, however, that have evaluated impact of farming apps on agricultural yields or reductions to pollution. There is also a lack of studies that summarize what information or tools, that can be provided through a mobile app, are most useful for farmers.

This gap in understanding could be a source of wasted time and effort for both developers and farmers if not rectified. For instance, the USDA ran a hackathon in 2015 that asked competitors to develop agricultural apps for farmers using USDA data. The grand-prize winner's app submission page received only two comments, with one saying,

"As a farmer its (sic) interesting to view this data but I'm not finding any insight to gain from it. Anyone already in the business will know what the neighbors grow and crop price history" (Lee, 2015).

If society is to transfer to more efficient farming through mobile apps, there needs to be an increased understanding of what farmers need and how developers can deliver it. This

paper will contribute to existing literature by attempting to answer the question: How can precision farming be successfully implemented through an app?

I. Literature Review

Background

The movement towards precision farming is in succession to the agricultural practices used during what is often referred to as the Green Revolution. First coined by William S. Gaud, administrator for the United States Agency for International Development (USAID), the term Green Revolution refers to the period between the 1960's and 1970's when new technologies were urgently developed to increase food production required by growing populations (OER Project, 2019). This included technologies such as high yield engineered seeds, artificial pesticides and fertilizers, and increased watering through irrigation methods. The technologies, which were originally developed in the United States (U.S.), were shared with countries including India, Indonesia, and the Philippines to combat hunger. They were also used as a political ploy. During this time, the U.S. was concerned about growing communist regimes and worried that impoverished countries would be particularly susceptible to Soviet Union and Chinese influence (OER Project, 2019). It was thought that sharing these agricultural technologies would reduce starvation in the world while aligning the chosen countries with the democratic and capitalist ideology of the U.S. The phrase "Where hunger goes, communism follows." was used to convey this idea (Tawil, 2020).

The agricultural technologies shared with countries of concern were then adapted to the needs of the local environments, in many cases, with great success. In India, for example, new high yielding rice and wheat varieties were developed, and techniques were employed to supply crops with large quantities of fertilizer and water. Techniques like this resulted in a doubling of rice and a quadrupling of wheat productions in Asia between the years of 1960 and 1990 (OER Project, 2019). It is estimated that millions of people avoided starvation due to the technological advances of the Green Revolution (Pingali, 2012).

Despite the role it played in massively reducing hunger, the Green Revolution is critiqued for its unsustainable success. This type of production uses resources at rates that cannot keep up with the world population growth. The techniques have also harmed the environment with excessive use of fertilizers, pesticides, and water, and single variety agriculture has lowered biodiversity and depleted soils of nutrients (Tapan Kumar Nath, 2016). The Green Revolution also had an arguably limited impact even within the chosen countries. For example, the more impoverished and rural areas often went without receiving technological opportunities due to issues such as insecure land occupancy, low credit, and discriminatory policies towards female farmers (Pingali, 2012). African farms also did not initially benefit from the introduction of Green Revolution technologies because they were only suitable for areas with high population densities. Higher-yielding crops were also more appealing to countries that had less available arable land. This was not a problem for Africa in the past so there was less incentive for African farmers to incorporate the techniques. Agricultural investments and developments in Africa have become more frequent in recent years as their populations grow and their available land reduces (Pingali, 2012).

Today, society still faces the urgent issue of escalating demands for agricultural production. The Food and Agriculture Organization of the United Nations (FAO) estimates that by 2050 there will be more than 9 billion people living on Earth. Population growth combined with rising incomes will result in a 70 percent increase in food demand (FAO, 2011). At the same time, the practices used during the Green Revolution and for industrial level farming today destroy the land needed to continue producing food and sicken the people who live on the land. A high level of cancer cases in Punjab, India, 90 per 100,000, was found to be linked to the fact that local water was contaminated by the over use of chemical fertilizers in nearby agriculture (Thakur et al., 2008). Organic farming techniques are typically more sustainable and better for the environment, but studies show that their yields are lower than industrial productions (Jouzi et al., 2017).

Precision farming

How can industrial level farms incorporate organic farming practices while *increasing* yield levels? Precision farming (PF), also referred to as precision agriculture or smart farming, is one approach amongst others that aims to answer this question. PF is a production methodology that aims to pinpoint the exact needs of crops according to real-time data and information technology as opposed to uniform treatment according to predetermined conditions. Within field variability is considered and sections are treated only as need be. It enables farmers to increase production and income through better crop and animal monitoring and decrease pollution by giving more precise inputs of water, fertilizer, and pesticides (Geospatial World, 2017).

Lowenberg-DeBoer and Erickson (2010) define two interpretations of precision agriculture. The first interpretation focuses on technology such as global positioning systems (GPS) and variable rate technologies (VRT) that help farmers plant, fertilize, and harvest more efficiently. The other idea emphasizes the natural variability in soil, climate, plants, and animals and how these interact with specific inputs instead of standardized applications. Lowenberg-DeBoer and Erickson point out that the utility of certain types of precision agriculture varies from place to place even within regions due to "differences in soils, crops, farming systems, and social structure" (Lowenberg-DeBoer & Erickson, 2010, p. 3). This means that certain techniques and technologies that are successful in one part of the world may not work in others. For example, over 90 percent of combine harvesters in Argentina are equipped with GPS while in North America only about one-third of combines use this technology. This is because it is common that North American farm owners spend time operating their machines and know their fields intimately enough that GPS wouldn't provide any additional information. In Argentina, often farm managers don't use the harvesters themselves and the GPS helps them coordinate activities such as seeding and spraying with employees (Lowenberg-DeBoer & Erickson, 2010).

Who could use precision farming?

The two interpretations of precision agriculture explained in the previous paragraph are both important to its utilization. Even without the use of technology, the PF approach can be initiated through advice or suggestions given between farmers or by

experts. Some farms might make use of expensive and large-scale technologies, while in other situations an understated PF tool might make more sense. For example, in Africa, most farmers till the land by hand and animal power. Precision agricultural techniques are already common practice, but without the use of technology, especially on smallholding farms. For example, in Tanzania tea farms are divided into sub-fields and given customized amounts of inputs by hand according to needs of each individual block (Lowenberg-DeBoer & Erickson, 2010). Some precision agriculture technologies popular for other parts of the world, such as GPS and VRT, don't make sense for smallholder farms in Africa. Since farming is often done by hand, GPS on harvesters isn't applicable, and VRT is intended for large scale farms where large quantities of inputs are given which also doesn't apply to these types of smaller farms. The extensive use of cells phones in Africa, on the other hand, provides an opportunity to incorporate PF technology that can covey crop information straight to farmers. Lowenberg-DeBoer and Erickson suggest remote sensing as a potentially useful technology to give site specific information. Satellites or drones could monitor weather, pest, or nutrient deficiency problems through high resolution imagery, which farmers could be alerted to through their mobile phones. The authors state that to the best of their knowledge no technology such as this has been widely adopted in Africa yet (Lowenberg-DeBoer & Erickson, 2010).

What about PF technologies that are more substantial? Blasch et al. (2022) conducted a survey on Italian farmers asking them about their willingness to try three levels of PF: non automated, partially automated, and fully automated technology, with the price of each indicated. The participants were also asked how much they value certain benefits of PF such as yield increases, water quality, reduced fertilizer bills, and receiving personal advice. The study revealed that the Italian farmers with medium ranged incomes cared more about increased yields, fertilizer savings, and personal advice than farmers with high incomes. They also were more inclined to use fully automated technologies than both high- and low-income farmers. Farmers with lower incomes were the least likely to use partly or fully automated PF technology. Small farm owners cared less about water quality, fertilizer savings, and personal advice than larger farm owners, but there was no significant difference between large and small farms for technology preference (Blasch et al., 2022).

Willingness to use PF technology seems to depend more on how much benefit these technologies would bring farmers rather than how much money they can afford to spend on it. This stresses the importance of implementing suitable technology according to the farm specific circumstances. It also highlights the possibility of PF's implementation in all sorts of farms, not just those with the highest income or the largest farm.

Are farmers interested in mobile applications?

There have been several studies dedicated to evaluating if mobile phones, without the use of apps, increase farmers' agricultural yields or their ability to establish a competitive market, and they have positive results[1]. For example, Quandt et al. (2020) studied the relationship between mobile phone use and agricultural yield in rural communities in Tanzania. The researchers recorded farmers' perceptions and self-reports of the phone's impact on their farming outcomes as well as quantitative data on how many SMS messages were sent and how many calls each farmer made. Their results show a positive correlation between farmers' self-indicated phone use for agricultural related activities and yields. Many farmers reported that using their phones increased their profits as well as decreasing the cost and time invested into farming. Of those farmers surveyed who had cell phones, the most popular mobile phone uses for agricultural purposes were for discussions with friends and family which was utilized by 75% of respondents, selling crops (70%), talking to an agricultural extension agent (65%), gaining knowledge about farming practices (65%), and buying seeds or fertilizer (62%). There was no statistical significance, on the other hand, when they evaluated general phone use by the number of calls and SMS messages against crop yields. This indicates that merely using a cell phone may not influence productivity, but *how* farmers use their phones is a larger determinant of agricultural success. Only 6.3% of farmers surveyed reported owning a smart phone which makes use of "agricultural information services" rare and limited the extent to which the researchers could analyze or predict the impact of an agricultural mobile app (Quandt et al., 2020, p.8).

[1] See Khan et al. (2022) for additional context

What if farmers did have access to smartphones? Jaafar and Kharroubi, (2021) conducted a survey on Lebanese farmers to analyze how willing they'd be to incorporate an irrigation mobile app into their water management practices. They also looked at variables that could have influenced answers such as age, nationality, and region. 90% of farmers said they thought that enhanced irrigation management could increase their farm's efficiency, and a "similar percentage" stated they would be willing to use free apps to help them manage their crop irrigation (Jaafar & Kharroubi, 2021, abstract). This was reduced to 57% when asked about their willingness to pay for an app. Farmers that pay more for water and electricity were more willing to pay for an app (Jaafar & Kharroubi, 2021, abstract).

Abdullahi et al. (2021) conducted a survey experiment in northwest Nigeria where farmers were evaluated on attitudes and knowledge towards using mobile phone apps for agricultural purposes. They were also asked about the constraints they faced in using apps for their daily work. Most participants had a favorable attitude towards agricultural phone apps, with a particular emphasis on apps that help transfer information between farmers. The most frequent constraints felt by farmers towards mobile applications were high phone costs, lack of encouragement and awareness, and poor network connection. Their results show that knowledge of mobile phone apps results in more positive attitudes towards app use as well as less perceived constraints. Therefore, the authors state that mobile application training would enhance knowledge and reduce learning constraints to encourage agricultural app use (Abdullahi et al., 2021).

So far, the literature has suggested a willingness by farmers to use precision agriculture and, if feasible, incorporate its techniques through mobile phone applications. Now, it is important to evaluate what potential *apps* have in assisting farmers with more efficient agricultural practices. In the next section, this paper will look at a few agricultural apps that have been recently implemented into society.

What agricultural mobile apps exist already?

A study conducted by the Mechanical Engineering of Biosystems Department of Razi University in Iran evaluated the effectiveness of a water quality testing technology now used in an android application called WaterApp. Establishing proper water conditions is

important for aquaculture because it influences the quantity and quality of aquatic plants and animals produced (Heidari et al., 2021, p.2). The technology used in WaterApp can assess water conditions through images taken by a mobile phone. The researchers collected water samples from different periods of time over 2 weeks from a carp fishpond. The water samples were poured into a glass box and a "Bluetooth remote monopod model YUNTENG YT-1288", in other words a selfie-stick, was used to capture the image at three different specific levels (Heidari et al., 2021, p.3). Using an artificial neural network, the app's technology was successfully able to determine the water quality parameters of pH, EC TDS, and Turbidity (Heidari et al., 2021, p.3). The WaterApp has been rated highly but with only a few reviews on Google Play so it will not be part of this paper's analysis.

Soil scientist Jeff Herrick, who works for the USDA's Agricultural Research Service, released two mobile phone apps aimed at helping farmers across the world obtain and share knowledge with each other about how to maximize land productivity and protect resources. The apps' information run on the Land Potential Knowledge System (LandPKS) which is a network of free databases that enable the use of technologies in the apps such as soil mapping, GPS field tracking, and other tools accessible over the internet. One of the apps is called LandInfo which focuses on soil, land cover, and climate data. It also provides feedback to users about average monthly temperatures, rainfall, and more. The other app, LandCover, is a data collection tool that simplifies storing data about land-cover inventories and monitoring. Both programs have been converted into one app, LandPKS, with the addition of a new module called LandManagement which functions as an agricultural recordkeeping program (Suszkiw, 2017). LandPKS has received very good ratings in both Google Play and the Apple Store and will be used in this paper's analysis. In 2019, a pilot test of the LandPKS smartphone application was conducted in multiple Ethiopian regions to analyze its potential in that context in combination with the regions' current land use practices (Irkiso et al., 2020) . The results of the pilot test showed potential, and since then the Ethiopian Ministry of Agriculture has adapted LandPKS for land-use planning and has "trained hundreds of its staff to use LandPKS" (Kerchof, 2021). Lasting results of LandPKS on Ethiopian agriculture has not yet been evaluated.

Where are we now?

According to the literature cited in this paper, in various parts of the world farmers show an inclination to incorporate PF techniques or technology into their farming practices. There is a wide range of PF methods, from simple advice to fully automatic VRT systems which provides opportunities to all types of farms. Mobile applications seem to be particularly suitable for farms that require less high-tech machinery but could use a low cost and convenient tool to share and receive information. There is a lack of research on how existing mobile apps have influenced farming practices or resulting yields. This makes it hard to understand what makes an agricultural app successful and what could be improved upon in the future. Studies show that while there is potential, apps must provide tools that are relevant to farmers' needs, must have as few constraints as possible, and be worth the cost in a farmer's opinion, if there is any. This paper will attempt to gather more specifics by analyzing reviews on existing agricultural apps for android phones.

II. Theoretical Framework

To determine how PF can be successfully integrated into an app, it is important to see how well apps that already exist have been received by farmers. Academics and politicians can guess how well PF technologies would work for farmers in specific areas, and developers can try to incorporate those functions into an appealing app, but a critical step remains. Evaluating user reviews is essential in maintaining apps once they are initiated so that they can meet and adapt to changing user needs. Large corporations such as Johnson and Johnson, Vodafone, and Deutsche Bank use textual analysis software to automate analysis from reviews on websites such as Google Play, Amazon, and the Apple Store (*Appbot for Product Managers*, n.d.). In this paper, textual analysis will be used in a similar fashion as the software that is available for purchase, albeit on a much smaller scale and with simpler methods.

Di Sorbo et al. (2016) present one approach to automated user review analysis called SURF (Summarizer of User Reviews Feedback). This method first detects user intentions such as whether they are complaining about a bug or wanting a new feature. Then, the intentions are assigned to a pre-defined topic category that it applies to, for example pertaining to the

graphical user interface, price, or the company. Then, results are summarized through sentence scoring and extracting important information (Di Sorbo et al., 2016). The SURF method seems to be effective for identifying what popular topics are getting attention at the moment so developers can quickly make needed changes. Since this analysis will work with combined datasets from multiple apps, the specific topics are unknown. Therefore, SURF was not a suitable approach.

Guzman and Maalej (2014), developed and evaluated a textual analysis method that uses feature extraction, sentiment analysis, and topic modeling to reveal important and frequently mentioned app features. This approach has an emphasis on discovering what features and topics are the most significant (Guzman & Maalej, 2014). This aligns with this paper's goal of highlighting what exactly makes an agricultural app successful or not. Thus, the textual analysis method used in this paper was based off the Guzman and Maalej design with some changes. Instead of grouping similar features into larger topics to evaluate, topic modeling was used first to identify broader subjects. Topic modeling gives an overview of popular subjects, but it doesn't imply any sentiment towards them. In other words, it doesn't tell us if people are happy about this topic or unhappy about it. To gain more insight into how people feel about these topics, features were extracted while paying attention to how they related to the larger topics. Sentiment analysis was then conducted on specific features. Unlike the Di Sorbo et al. and Guzman and Maalej approaches, features were manually looked at by inspecting individual reviews. This was feasible since the features were, for the most part, not grouped together, making the number of reviews per feature smaller than in the other two studies.

Considering previous studies on farmer attitudes towards using mobile agriculture apps, cost, ease-of-use, and the specific tools offered are the main deciding factors concerning how willing farmers are to start using them. Additionally, an initial scan of agricultural app reviews revealed that many comments are about bugs with the app's user interface or an opinion about the price for certain tools or versions.

Due to this, the analysis will first group apps by which tools they offer so that more accurate assumptions can be made about each identified feature. This paper hypothesizes

that both cost and ease-of-use will play an important role in determining the success of agricultural apps.

III. Methodology

A. Data Collection

General research was conducted about the most popular farming apps to find those that would provide the largest number of reviews. Initially, reviews from both Google Play and the Apple Store were to be collected. It was discovered though, that the Apple Store website restricts the viewer to seeing only a limited and small number of reviews for each app. Google Play, on the other hand, allows access to a large number. In this project, the method of extracting reviews was web-scraping without the use of an API. This technique would be inhibited by the setup of the Apple Store website, so it was determined that reviews from Google Play would suffice. After finding 40 apps that had at least 5 reviews each, the apps were sorted into four different groups depending on what aspect of farming they support. Since most apps have multiple functions, the main function of an app was used to categorize it. In a few cases when an app had multiple main functions, it was placed into two different groups. Most types of agricultural apps were used if they had enough reviews, even if they didn't specifically mention precision farming, precision agriculture, or smart farming. For this analysis, any tool that helps farmers with efficiency or accuracy can be considered precision agriculture because it is essentially helping them be more effective.

The first group of apps are referred to as Data Collection and Management. The main purpose of these is to help farmers with collecting and storing their own data and observations, record keeping of things such as expenses and rainfall, and for making calculations based on their own specifications. For example, *Tank Mix Calculator* enables farmers to calculate pesticide mix amounts as well as the number of loads required to spray their fields by inputting their acreage, tank size, carrier volume, and by selecting which chemicals they are using.

The second type of app group was named Information and Education. These apps have a focus on enhancing farmers knowledge on best agricultural practices as well as providing support when they encounter problems. *Yara CheckIT* provides users with a library of crop photographs that show the signs of different nutrient deficiencies with additional information about how to treat the deficiency. Other apps, such as *AgriMedia TV : Hi-Tech Agriculture* provide agricultural education through audio and video productions.

AgriMedia TV : Hi-Tech Agriculture has a market rate and buying and selling feature so it was placed into the Market Place and Social Network app group as well. Apps in this group have an emphasis on connecting farmers to each other to buy and sell equipment, hire labor, as well as get the most up-to-date market prices on livestock and crops. Connecting farmers not only increases fair market values, but also enables farmers to learn important information from each other.

The last type of app group identified was Advanced Technologies. Apps in this group have features that include technology that is more complicated than just textual or visual information such as AI Diagnostics, GPS Navigation, and Satellite Imagery. For example, the app *Plantix* detects crop diseases and pests through AI identification. The farmer need only take a picture of the plant in question, and they will receive a diagnosis of the problem along with possible solutions.

Web Scraping

After organizing the apps into their corresponding groups, web scraping was conducted on each Google review page using R and RStudio[2]. Google Play review pages have semi–Infinite Scrolling. This means that as users scroll down new content is automatically loaded, but only a certain number of times. Once a certain number of automatic page loads have taken place, a "Show More" button appears and requires the user click it to continue reading reviews. Due to this constraint, the package RSelenium was used to automate this process in attempt to load as many pages as possible. Inspiration and understanding for this process was gained from JLaw's blog on R-Bloggers (Blog, 2021) .

[2] GitHub repository for this analysis: https://github.com/KathrynMalchow/Thesis_Analysis

Once the pages had been loaded, the HTML objects of interest were collected from the page. This included, for each review, the reviewer's name, the date the review was made, the number of stars the app received, and the full text of the review. Table 1 shows the different apps in their categories as well as how many reviews were collected for each app. Often, the Google Play interface would interfere during the browser automation process, forcing the newly loaded pages to disappear. In these situations, multiple attempts were made repeating the process described above until an adequate number of reviews were collected. This means that the number of reviews collected might not accurately represent how many reviews have been made in total for each app. Ultimately, almost 3,700 reviews were extracted from Google Play.

Table 1. Number of Reviews Collected Per App

Data Collection and Management		**Market Place and Social Network**	
LandPKS	20	AgMobile	84
Farm Logs	153	Cattle Market Mobile	97
Grazing Calculator	19	Farmpost App	27
Tank Mix Calculator	114	Tractor Zoom: Farm Auctions	8
Canopeo	15	TractorHouse	212
GPS Fields Area Measure	80	AgriMedia TV : Hi-Tech Agriculture	840
fieldmargin: farm management	124	Agri Setu - Agriculture App for Smart Farming	47
Farmer's Wallet - Farming app	120	Kisaan Suvidha - किसान सुविधा	42
Farm Management Pro	120	BigHaat Smart Farming App	120
Soil Sampler	68	EzyAgric Farmer	100
Fertilizer Removal By Crop	49		
My Crop Manager - Farming app	52		
total	**934**	**total**	**1,577**

Information and Education		**Advanced Technologies**	
LandPKS	21	AgriBus: GPS farming navigator	47
ID Weeds	28	Field Navigator	40
Yara CheckIT	111	FieldBee tractor GPS navigation	96
SoilWeb	14	OneSoil Scouting: Farming Tool	65
AgriApp	80	Agrio - Precision agriculture	80
AgriMedia TV: Hi-Tech Agriculture	840	Plantix - your crop doctor	80
BharatAgri: Smart Kissan App	160	BigHaat Smart Farming App	120
Agri Farming - App for Agri, Farming, Gardening	41	SCOUTING - Automate field diagnosis	160

Agriculture: Farm Extension Manager	80	xarvio® FIELD MANAGER	23
Farming Solution	20	PlantSat- Satellite Precision Agriculture	24
total	**1,395**	**total**	**735**

B. Text Preprocessing

Language Translations

Many of the apps that were chosen to analyze can be downloaded from anywhere and their functions are not focused on any one region's needs. PlantSat- Satellite Precision Agriculture, for example, states that their remote sensing technology can be used to view crops all over the world. The app's reviews confirm that people from many areas of the world have downloaded the tool, some having success with its functions and others not. Some of the apps that were chosen for their large number of downloads and reviews have a focus on Indian agriculture. These apps are BharatAgri: Smart Kissan App, AgriMedia TV: Hi-Tech Agriculture, Kisaan Suvidha - किसान सुविधा, and BigHaat Smart Farming App. Due to the global nature of the apps used in this analysis, translation was needed to utilize as many reviews as possible. The most frequent languages appearing in the scraped reviews, besides English, were Gujarati and Hindi, but other languages were translated as well. To automate the translation process as far as possible, the TranslateR package was used to facilitate the use of Microsoft Azure's translation API.

Once the app reviews were translated, the text was preprocessed through two different methods, one in preparation for topic modeling and the other for feature extraction and sentiment analysis.

Topic Modeling

For topic modeling, review text was separated into individual word tokens. Stop words were then removed using a custom data set that contained the stop_words data frame from the Tidytext package as well as additional words that were deemed necessary. The "stop_words" data frame contains 1149 commonly used English words and for all app groups the words "app", "star", "fix", and "please" were added in addition. For the Markets and Network and Advanced Technology groups the words "farmers", "farm", and "farmer" were also included because they appeared very often. App names, such as BigHaat were

additionally removed if they appeared too often in the results. These words were taken out because they provide little to no insight into the context of reviews and inhibit the viewer from seeing more informative words. Next all letters in the word tokens were made lowercase, and all punctuation and numbers were removed. Word stemming was tested to see whether this enhanced topic model results. Overall, removing the ends of words didn't provide much more insight than not doing so, and it made the topics much harder to read, so word stemming was not performed.

Feature Extraction and Sentiment Analysis

Before extracting important features from the reviews, the review text was parsed into individual words that were organized through part of speech tagging (POS) which identifies the words' grammatical roles in the sentences. For their study, Guzman & Maalej manually inspected 100 reviews and determined that nouns, verbs, and adjectives are more likely to describe features than other types of words. Therefore, only those were kept in this study as well. Lemmatization was also used so that all variants of a word were changed to its root form. The same custom data frame of stop words used for topic modeling was removed, but the Information and Education, Market Place and Social Network, and Advanced Technology app groups had additional words taken out including "farmer" and "application."

C. Analysis

Topic Modeling

The tokens created for topic modeling were formatted into a document feature matrix, which was then subjected to latent Dirichlet allocation (LDA). LDA is a popular statistical model that proposes that every document, in this study's case - review, is a combination of multiple topics. It helps extract "latent" or hidden topics within the reviews that might not be seen by manually reading them. To extract these topics, the LDA model returns an output of words that are determined to be statistically significant to each other. Each app group was put through a LDA process multiple times to determine the number of topics that would generate the most insightful results.

Feature Extraction

To extract features from the reviews, the package Udpipe was used to find word collocations. The Udpipe package maintainer, Jan Wijffels, defines collocations as "a sequence of words or terms that co-occur more often than would be expected by chance"(Wijffels et al., 2022, p.43). The package's collocation function determines how likely two words are used together rather than being independent with three different statistical equations: pointwise mutual information, mutual dependency, and log-frequency biased mutual dependency. The function was set so that collocations of both bigrams and trigrams could be found, but since it was decided to only consider collocations that appear at least 3 times, no trigrams were generated. For the purposes of this study, the frequency and uniqueness of the collocations was used to determine which features should be used for sentiment analysis later. Table 2 provides an example of the top 10 most frequent features found in each app category. To make the analysis more insightful, features that were found in multiple app groups, such as *user friendly* were only analyzed for one category, and other less frequent but interesting features were chosen for the other groups.[3]

Table 2: Most Frequent Features per App Group

Data and Management		Market Place and Social Network		Information and Education		Advanced Technologies	
keyword	**freq**	**keyword**	**freq**	**keyword**	**freq**	**keyword**	**freq**
user friendly	12	user friendly	9	good agriculture	15	user friendly	16
rain fall	8	agriculture student	8	crop information	10	product service	6
waste time	8	good information	8	crop advisory	9	customer care	5
keep track	8	customer care	7	provide information	9	save track	5
free version	8	good agriculture	7	information crop	9	save field	5
accept term	7	error building	6	excellent application	8	cool feature	4
accept button	7	product service	6	nice application	8	help lot	4
record keeping	7	provide information	6	nice information	8	bad experience	4
income expense	7	building list	5	weather prediction	7	crop include	4
add feature	7	piece equipment	5	agriculture student	7	excellent application	4

[3] Some features chosen to analyze are not featured in table 2.

Sentiment Analysis

App review text is generally short compared to other forms of text in other textual analysis studies (such as speeches) and often contains incomplete sentences and frequent spelling mistakes. For this reason, it was important to find a sentiment analysis tool that could interpret this short and informal text well. According to a study conducted by Thelwall et al. (2012) SentiStrength, a sentimental classifier, is an effective tool for detecting positive and negative sentiments in social media texts. SentiStrength assigns both a positive and negative score to each text document (in this case, review) because social media text can have both positive and negative attributes. For example, "the app is very useful but it's so ugly" has both positive and negative sentiments. SentiStrength assigns each text a positive value from 1 (neutral) to 5 (very positive) and a negative score of -1 (neutral) to -5 (very negative). In addition to using a lexicon to determine these sentiments, SentiStrength also employs additional language rules to better interpret meaning. These include a spelling correction algorithm and identifying booster words, repeated letters, and punctuation that strengthens the sentiment of the following words. For example, "it is *really* nice" or "this feature is so *badddd*" or "I love it*!!*" would all gain 1 point extra either positively or negatively (Thelwall et al., 2012).

After the collocations were determined, 4 or 5 interesting and frequent features from each app category were chosen to evaluate. Reviews that mention the features were grouped together and were ran through the SentiStrength tool, which is a separate program that can be downloaded from the SentiStrength website[4]. Table 3 provides one simplified example from each app group demonstrating how SentiStrength assigns positive and negative sentiment.

[4] SentiStrength Website: http://sentistrength.wlv.ac.uk/

Table 3: Example Sentences and their Sentiment Scores

App Category	Sentence	Scoring Rational	Score
Data and Management	"Terrible. Dont waste your time."	Terrible[-3] Dont waste[-1][Negated Due To Previous Word] your time.	(1, -4)
Market Place and Social Network	"hay equipment, wont pull up when u click on a piece of equipment says building error. everything else works fine"	hay equipment wont pull up when u click on a piece of equipment says building error[-1] everything else works fine[2]	(3, -2)
Information and Education	"This is an easy-to-use and excellent app which is continuously improving! May be due to poor internet connection here where I am, the server is sometimes down and not responding."	This is an easy-to-use and excellent[3] app which is continuously improving! [1] May be due to poor[-1] internet connection here where I am, the server is sometimes down and not responding.	(4, -2)
Advanced Technologies	"Good to diagnose the problems in plants, very helpful"	Good[1] to diagnose the problems[-1] in plants, very helpful[1][1 Last Word Booster Strength]	(3, -2)

Table 3 shows that the detections made by SentiStrength aren't always correct. For example, the word "problems" in the last review was determined to have a negative sentiment, but this review is entirely positive. Even though the scores assigned are sometimes partially inaccurate, this sentimental analysis proved accurate enough to gain an insight into the general attitude towards the different app features. The positive and negative sentiment score for the features in each app category were averaged to see whether they were more negative or positive. These averaged scores were then compared to the average star rating from reviews mentioning those features to check whether the sentiment scores accurately reflect how people felt.

IV. Results

A. Data and Management Apps

The optimal number of topics for the Data and Management app group was determined to be 12. Table 4 shows the topics generated ordered by the most prevalent topics throughout the reviews to the least, along with the 10 most frequent terms belonging to each topic also in order of prevalence. Gamma, in this table, represents the percentage of reviews that contain the topic. Topic 9, for example, exists in about 7 percent of all reviews in this data set.

Topic 7 seems to relate to the tools within the apps, and how they make farming and record keeping easier. This supports the hypothesis that ease-of-use is a popular topic. The other argument, that cost is one of the most important issues, is less supported in this table, as it appears in topic 5 as only the 6th most frequent topic. Nevertheless, the issue of cost still makes an appearance

In addition to topics 7 and 5, topics 13 and 1 are also emphasized in table 4 because their words seem to have coherence together. Topic 13 identifies with what appears to be specific features in the apps that help farmers measure things, and the word GPS suggests that reviewers may be talking about managing their fields. Accuracy is the most frequently used word in this topic, which shows that how effectively the tools measure the fields is of importance in these reviews. Topic 1 contains words that relate to the mobile device and the user interface of the apps such as phone, screen, terms, button, and accept. This suggests that there may be some issues or successes with functionality of the apps on farmers' phones. This relates to the ease-of-use hypothesis as well. All these topics arise in varying ways in the feature review in the following sections.

Table 4: Data and Management Topics by Prevalence Across all Reviews

Data and Management

Topic	gamma	Terms
★ **topic7**	0.07208857	**easy, farm, keeping, record, makes, farming, easier, tool, recommend, track**
topic9	0.07014817	love, farm, tool, helpful, management, livestock, mapping, easy, super, update
topic10	0.06845102	nice, add, chemicals, option, soil, view, records, ability, farmlogs, farms
topic2	0.06842388	time, simple, wonderful, crops, nice, waste, upgrade, bad, info, crashes
★ **topic13**	0.06802748	**accurate, measure, easy, measuring, features, gps, feature, measurement, ads, distance**
★ **topic5**	0.06792785	**free, data, version, money, month, pay, tracking, worth, found, activities**
topic6	0.06782665	rain, rainfall, update, fields, farmer, history, charging, fall, record, farm
topic11	0.06722893	user, excellent, friendly, farmers, expenses, experience, track, customer, idea, stop
topic14	0.06673089	map, version, add, maps, downloaded, fields, google, accounting, premium, useless
★ **topic1**	0.06640828	**phone, accept, screen, terms, button, android, past, totals, time, acres**
topic15	0.06616858	track, helpful, accurate, nice, team, amazing, features, developer, lot, helped
topic4	0.06487478	data, time, save, notes, handy, input, measurements, recommend, users, information
topic8	0.06271046	crop, stars, website, lot, yield, pro, option, easy, change, units
topic3	0.06177150	application, expenses, day, log, months, takes, activities, time, simple, paid
topic12	0.06121294	field, list, love, report, job, rate, plant, expense, pretty, records

Next, features were extracted from the Data and Management dataset using the word collocations as shown in Table 2. Table 5 below shows the selected features along with the average positive and negative sentiment scores and average stars given by those reviews containing the specified features. According to the star ratings, the sentimental analysis accurately identified if reviews had more positive or negative sentiment. For example, *keep track* has an average positive sentiment score of 4.45, which is very high, and a negative score of -1.15 which is almost neutral meaning no negative sentiment. The star rating aligns with these scores with an average of 4.35 stars given.

Table 5: Data Collection and Management Features

Feature	**Average Number of Stars (1-5)**	**Average Positive Score** **1 (neutral) — 5 (very positive)**	**Average Negative Score** **-1 (neutral) — -5 (very negative)**
user friendly	3.82	2.55	-1.36

rain fall	2.38	2.17	-1.79
waste time	1.80	2.00	-2.20
keep track	4.35	4.45	-1.15
free version	3.25	2.75	-1.88

The reviews pertaining to each feature were then manually reviewed to gain deeper knowledge of their meaning rather than just "good" or "bad."

user friendly

Most reviews simply say "user friendly" or "not user friendly" but a few go into more detail about what exactly they liked or didn't like about the usability. One reviewer states,

> "There are far too many buttons to sort through for the average farmer who has stuff to do. Labeling buttons with icons in addition to the text would … be more user friendly."[5]

This opinion supports the paper's hypothesis that farmers need apps that they can easily get used to without much time spent on learning how to use the interface. Another review says,

> "Already using a bit and doing a trial with one of my managers to see how we can incorporate this software into the farm. Having our weekly meeting today and think well try and do most of our planning on it to see how it goes."

This suggests that even if the app itself works great and is user friendly, it must fit in with how the farm is managed and not the other way around.

rain fall

Most reviews that mention rain fall are concerned with how accurate the apps are in measuring rain amounts and the price of this feature. There seems to be an equal number of reviewers that are happy with the rainfall accuracy, those that call it "so-so" and those

[5] All quotes pertaining to reviews were originally collected from Google Play, then edited and translated by the author. The full set of quotes can be accessed through the replication materials at: https://github.com/KathrynMalchow/Thesis_Analysis

that are completely dissatisfied with it. This seems to depend on the app in question and the location of the farm.

What is more interesting, is how much monetary value farmers place on a rain tracking feature. Many of the reviews that mention the accuracy of a rain fall feature also mention their rain gauge or the internet. For example,

- "Rainfall accuracy was only so-so compared to our rain gauge but at least the app showed you rainfall history. Now they're charging $29 per month for that …!"
- "*All i used* [emphasis added] was the rainfall tracking *(free information online)* [emphasis added] …. This app made it easy but Im not spending $29 a month or any amount for free information and a simple record of history."

Basic understanding of farming practices and the number of reviews that mention it both demonstrate how essential tracking rainfall is in successful farming. Still, many of these reviewers consider rainfall tracking a tool that should be inexpensive considering that they already have a rain gauge, which is more trustworthy than an app, and the internet to check amounts. Multiple reviewers call the developers "greedy" for increasing prices. The previous two reviews show that the rainfall *history* tracking is a valuable feature that is unique to apps. Still, even when including the convenience of having rainfall history directly on an app, the general view seems to be that it should be low cost. One review mentions that they think 5 dollars a month for the rainfall history should be enough. Farmers are reluctant to pay a premium for a tool they already have in some other, less convenient, form. If it is at a fair price, though, farmers seem to be willing to adapt to new and more convenient methods. Consider the following review,

> "Rainfall tracking is very important to manage fertilizer applications among other things. I can look at the app and see if a farm 20 miles away got any rain last night. That beats going to the feed store and listening to all the old timers as they guess how much they got. I can just open the app and show them how wrong they are. Worth it's weight in gold for that reason alone!"

waste time

The reviews that mentioned wasted time are all about the apps in question not working properly. This includes both field measurement inaccuracies and app updates causing bugs. Users are especially unhappy when they mention having paid for the apps' features.

keep track

Keeping track was one of the features that got very high reviews. The reviewers mentioning this feature seem to enjoy the benefits of tracking income, farm inventories, and purchases. One review especially appreciates the ability to share data with a whole farm team.

> "Fantastic. … The whole team has access to the data and its really improved our communication and teamwork skills as we all know what needs to be done. We always have a plan and we are always adapting to changes in weather and such …"

According to this reviewer, enhancing farm management through data collection and keeping track of work can boost productivity when the data is accessible to all farm hands.

free version

Most of the reviewers for this feature say that they only have the free version, but they are generally happy with it. Some mention that they would be willing to upgrade but the premium versions are too expensive, which are said to be $30 - $60 a month. One reviewer says they would be willing to pay around 60 AU ($42) a year.

B. Market Place and Social Network

The optimal number of topics for the Market Place and Social Network app group was set on 5, which are shown in Table 6. No topics generated for this group relate to cost, nor do any seem to be about ease-of-use. Topic 1 could be about the apps' usability because of the words easy, helpful, and friendly, but the other mismatched words make this assumption impossible. Topics 5, 4, and 3 were chosen because the words are more coherent. Topic 5 seems to be about acquiring agricultural knowledge, topic 4 is perhaps about the marketplace features that allow users to search for farm equipment for sale, and

topic 3 seems to be a mix of topics about the products one can buy in the marketplace, as well as the customer service.

Table 6: Market Place and Social Network Topics by Prevalence Across all Reviews

Market Place and Social Network

Topic	gamma	Terms
★ topic5	0.2383593	information, application, agriculture, excellent, farming, informative, agri, students, helpful, knowledge
topic2	0.1948226	nice, market, love, easy, awesome, prices, cattle, markets, local, helps
topic1	0.1935870	nice, easy, helpful, aap, user, hindi, language, application, friendly, che
★ topic4	0.1918404	update, search, equipment, time, load, location, error, version, list, lot
★ topic3	0.1813906	products, product, time, service, experience, team, quality, delivery, services, customer

Table 7 below shows the selected features and stars for the Market Place and Social Network dataset. This time, it seems the sentimental analysis less accurately identified positive or negative sentiment, at least for two features. First, *agriculture student* has an average of 4.93 stars, which is very high, but its positive sentiment score is only 2.33. This could be because the reviews pertaining to this feature didn't have sentiment, but merely said things along the lines of "it worked" or "it didn't work." This also applies to *product service* which also received high star ratings but relatively neutral sentiment. Second, the *piece equipment* feature has a very low star rating of 1.75, but its positive and negative sentiment scores are the same. The reasons behind this are investigated in the following sections.

Table 7: Market Place and Social Network Features

Feature	Average Number of Stars (1-5)	Average Positive Score 1 (neutral) — 5 (very positive)	Average Negative Score -1 (neutral) — -5 (very negative)
agriculture student	4.93	2.33	-1.07
customer care	2.80	2.00	-1.40
product service	4.69	2.54	-1.23
piece equipment	1.75	1.50	-1.50

agriculture student

Unfortunately, no information is provided about *why* agricultural students seem to like these apps. The reviews all state something along the lines of "good for agricultural students and farmers." This dataset contains reviews for the very popular AgriMedia TV : Hi-Tech Agriculture app as well as BigHaat Smart Farming App which are focused on Indian farming. Meaning lost in translating Gujarati and Hindi to English might be a reason why all the reviews are synonymous. One review says,

> "Here is the much-needed information for the village servant to attend the exam so that this app will be … very necessary for the farmers and the students associated with agriculture."

Perhaps many of those who mentioned *student* are taking this exam at the same school and were asked to review the app. This remains unclear.

customer care

The focus of reviews that mention customer care are complaints about ordering issues and not being able to reach customer service for help. A few reviews say customer care is good.

product service

Reviews that contain the words *product* and *service* are mostly very satisfied with the quality and price of products they are receiving, as well as the customer service of the apps that provided them with the goods. Some products that are mentioned are seeds, fertilizer, and pesticides.

piece equipment

All the reviews for this feature were negative. The main issue described here is bad user interface that makes seeing equipment for sale in the marketplace a cumbersome process. This supports the ease-of-use hypothesis.

C. Information and Education

It was necessary to create the Information and Education topic model with a large number of topics due to the variety of functions in some of the apps in this category. For

instance, BharatAgri: Smart Kissan App includes crop calendars, weather forecasting, soil and water testing, and chat and call support from agricultural doctors just to name a few. AgriMedia TV: Hi-Tech Agriculture also has a large variety of functions. Even when the topic model number was increased past the amount topics shown here, it did not seem to improve coherency of topics. Table 8 shows the 16-topic model for this app category.

Topic 4 is emphasized here because it seems to allude to smart or accurate weather forecasting or prediction. Topic 5 is also interesting because it is more obviously about languages by containing both the word language and listing English, Hindi, Malayalam, and Gujarati. Last, topic 16 is emboldened because, while it doesn't seem very coherent, the words found, weeds, identify, and quickly might allude to the fact that some of the apps in this category have picture galleries that help farmers recognize crop issues. None of the topics here seem to support the hypothesis that cost and ease-of-use are the most frequent issues concerning farming apps.

Table 8: Information and Education Topics by Prevalence Across all Reviews

Information and Education

Topic	gamma	Terms
topic9	0.06935642	application, excellent, information, service, yara, provide, simple, solutions, interface, protection
topic7	0.06821235	information, agri, nice, students, aap, agricultural, lots, useless, provide, daily
★ topic4	0.06631740	**crop, service, weather, advisory, india, smart, accurate, knowledge, prediction, purchases**
★ topic5	0.06483556	**application, nice, easy, data, language, superb, english, hindi, malayalam, gujarati**
topic11	0.06363331	nice, super, video, feature, products, response, list, soil, beneficial, details
topic1	0.06271866	helpful, agricultural, amazing, nice, love, related, helping, agri, awesome, service
topic14	0.06242826	crops, update, helpful, helps, features, review, keywords, provide, pictures, fertilizer
topic2	0.06226806	informative, application, add, excellent, products, customer, ma, na, poor, support
topic12	0.06201949	information, awesome, nice, organic, husbandry, knowledge, jay, info, animal, sector
topic13	0.06175522	related, easy, nice, informative, market, experts, option, rate, farm, rating
topic10	0.06173854	nice, apps, learn, amazing, update, information, time, solution, ag, horticulture
topic8	0.05964161	lot, product, absolutely, level, team, students, play, issue, internet, real
★ topic16	0.05903541	**knowledge, experience, agrimedia, found, features, weeds, identify, product, wonderful, quickly**
topic3	0.05867500	hai, helpful, people, india, beneficial, farm, chhe, platform, world, jai
topic15	0.05804218	download, unable, version, usefull, install, issue, team, love, helping, practice

Note: Topic 6 was removed from table due to incorrect translations

Table 9 shows the average star ratings and sentiment scores for the chosen features for the Information and Education app category. Like the Market and Social Network app group, the stars ratings are very high while the positive sentiment scores are not strong. They are a bit higher for this category though with even less negative sentiment.

Table 9: Information and Education Features

Feature	Average Number of Stars (1-5)	Average Positive Score 1 (neutral) — 5 (very positive)	Average Negative Score -1 (neutral) — -5 (very negative)
crop information	5	2.73	-1.23
crop advisory	5	2.65	-1.00
weather prediction	5	2.75	-1.00
local language	5	2.25	-1.00
internet connection	4.5	3.25	-3.00

crop information

The reviewers mentioning this feature like the apps for the "complete guidance" or "complete information" they provided. Some reviews go into more detail saying that the crop information is specified according to their area, sowing date of crops, and weather, and that the information is regularly updated. One reviewer says the updated information is the best feature in their opinion. Another review states,

> "I like this app *actually* [emphases added] it gives you proper information of crop … regarding which fertilizer and what kind of care we have to take. So overall it's best app, I ever seen and I recommend this app."

This review, as well as others, suggests that the user has experienced using other apps that did not provide accurate or useful crop information. This seems to illuminate how

important specified guidance and knowledge is to farmers, rather than just general best practice advice.

crop advisory

The reviews for this feature also mention that they like how precise and accurate the crop advice is. A few reviews mention in addition how easy the app is to use, specifically that the advice given is readable and understandable. This relates to the ease-of-use hypothesis.

weather prediction

All the reviews mentioning weather prediction simply say it is accurate.

local language

Reviews that mention this feature are happy that the app can be used in their local language, as well as the educational videos included. One reviewer requests the Marathi language be added as an option.

internet connection

One reviewer likes that the app they are reviewing works without internet connection so they "don't have to worry about internet service when in the field." Another person complains that the app doesn't work properly, perhaps due to poor internet service where they live. This shows that apps that can function without internet service are beneficial to farmers.

D. Advanced Technologies

Topic modeling for Advanced Technologies relieved three unsurprising but still relevant themes within this data group. Topic 2 seems to be about the accuracy of the GPS navigating features within the apps. The word "garmin" might refer to the company Garmin, that makes handheld GPS systems for hiking and other purposes. In the next section, manual inspection will determine why this word is frequently mentioned. Topic 1 seems to be a possibly related topic, since GPS can be used for a variety of purposes on fields such as mapping out property lines or for a more accurate knowledge of where farmers have already planted seeds or fertilized. Topic 9 includes words about plants,

diseases, and photos, so this points to some of the apps in the category that use AI to determine crop issues. Table 10 shows these selected topic models as well as some other topics that also seem relatively coherent but have themes that have already been covered in the previous sections.

Table 10: Advanced Technologies Topics by Prevalence Across all Reviews

Advanced Technologies

Topic	gamma	Terms
topic8	0.10591895	product, products, worst, support, customer, quality, service, delivery, services, pesticides
topic7	0.10541519	application, crops, helpful, farming, agriculture, add, lot, experience, features, helps
topic3	0.10387049	crop, user, friendly, information, team, potential, crops, properly, list, select
★ **topic2**	0.10163204	**gps, phone, accurate, accuracy, free, love, map, garmin, close, external**
topic5	0.10097864	easy, language, helpful, bad, option, tamil, understand, happy, idea, land
topic4	0.10052528	time, easy, excellent, simple, download, application, team, wow, ui, hours
★ **topic9**	0.10018247	**plant, plants, diseases, photo, disease, nice, identify, picture, time, application**
★ **topic1**	0.09983830	**field, fields, track, data, save, maps, love, recommend, waste, note**
topic6	0.09880830	nice, excellent, awesome, response, plantix, community, plants, lot, uninstalled, quick
topic10	0.08283032	install, guidance, day, solve, receiver, nu, add, filter, view, create

Table 11 shows that the chosen features for this app group received both positive sentiment scores as well as high star ratings. Only the sentiment analysis for *diagnose plant* seems possibly inaccurate since positive and negative got the same score.

Table 11: Advanced Technologies Features

Feature	Average Number of Stars (1-5)	Average Positive Score 1 (neutral) — 5 (very positive)	Average Negative Score -1 (neutral) — -5 (very negative)
save field[6]	4.07	2.67	-1.80
diagnose plant[7]	4.00	2.75	-2.75
cool feature	4.50	3.25	-1.25

[6] The features *save track* and *field spray* were added to this feature group because of topic similarity.
[7] The feature *pest disease* was added to this feature group because of topic similarity.

pay version[8]	4.75	2.50	-1.25

save field

The reviews mentioning this feature were primarily about apps that utilize GPS technology for saving field perimeters, recording where farmers had sprayed their fields, and monitoring the spraying process for better precision.

The reviewers are mostly happy with the accuracy of the apps' tracking features. From reading the reviews, the apps being discussed can either work with the user's built in phone GPS or an external device. Therefore, the name Garmin was assigned to topic 2 in table 10. Most reviewer's state that they are currently using their phone's GPS and it works well. One review says,

> "Has good accuracy with phone gps in a Motorola but will buy an external gps soon to improve accuracy a little. Works amazing spraying a spreading pasture and hay fields always within the 1 feet as I use for my overlap."

This user approves of the accuracy, giving a detail of how accurate (within 1 foot) the GPS is. Even though this already seems very accurate, the farmer is interested in being even more precise, which is good news for advancing precision agriculture. Another person mentions that the app they are reviewing is a "great simple app to use when try[ing] to … spray without a exspesive(sic) guidance system." Reviewers from previous parts of this study are annoyed when an enhanced feature is available for an extra subscription price; they feel like the developers are getting "greedy", which may or may not be true. In this case though, the GPS is accurate enough that farmers are pleased, but they are aware that if they bought an external GPS it could be even better. Like the reviews about the *rain fall* features from the Data and Management app group, some users seem to view app technology as convenient but unnecessary, and not as a real reliable "tool", like a rain gauge, for example. They might not expect apps to be perfect, and if they want perfect, they'll buy a "real tool." This might highlight that people view apps as nonprofessional

[8] The feature *reasonable price* was added to this feature group because of topic similarity.

software, which they would never pay so much money for. This could be for good reason; perhaps they have had negative experiences with glitches or obtrusive advertisements. It could also stem from the fact that the most popular apps are for entertainment, like social networking, and not for work (Koetsier, 2021). This is an interesting mentality that could change in the future as apps are further developed.

One issue that is repeated throughout many reviews is a glitch in one or more apps that is keeping farmers from being able to share their saved tracks with others. Functions for farmers to update each other on management situations and their spraying progress seems to be highly desired tools. One farmer suggests that there should be an option to mark "problem points", such as rocks or sink holes, in their field maps as well.

Additionally, one reviewer mentioned that the field measuring function in their app doesn't include elevations, so their measurements were incorrect. This points to the fact that flat surface level measurements may not be accurate enough, and more complex Geographic Information Systems (GIS) could be beneficial.

Some reviews for this feature mention ease-of-use issues as well. For example, one reviewer says that they could not switch between the map view in the app to their audiobook app without saving and exiting out of the mapping app completely. This suggests that developers should keep in mind that their app will be one of many on a phone, like a tool in a toolbelt. It should be easy to switch back and forth between it and other applications. Another ease-of-use issue that was spotted in the reviews for this feature was about learning to use the GPS measuring tool. Several reviewers mention having to take time to learn it or that they are still learning, but they all say it was worth it. One person suggests the developers use a video to explain setting up the GPS function.

diagnose plants

The reviews for this feature mainly state whether the apps' AI identification of crop diseases or deficiencies worked or not. About half the reviews say they were able to take a picture and have the plant identified correctly.

cool feature

Most reviews for *cool feature* just state that they like the app for this reason. One review mentions satellite maps, drone images, and soil maps.

pay version

Like the *agricultural student* feature from the Information and Education group, some of the reviews for *pay version* say identical phrases and they all thank the app BigHaat at the end of their reviews. These do not provide much insightful information. One other type of reviewer says they will update to the premium version if they enable saving curves in their field track records. They also state that the app is "clear and easy to read in use on a tractor and quite intuitive... which is rare."

V. Conclusion

This paper attempted to answer the question: How can precision farming be successfully implemented through an app? It was hypothesized that cost and ease-of-use would be important and frequent subjects in both the topic models and the features for all four app groups. Cost was most relevant for the Data and Management type apps, making an appearance in topic 5 of table 4, and with the features *waste time*, *rain fall*, and *free version*. Cost was also applicable to the feature *save field* and *pay version* for the Advanced Technology app group. Ease-of-use was a more prevalent subject than cost, also appearing the most in the Data Management group for topics 7 and 1, along with the feature *user friendly*. Ease-of-use was also relevant to the features *piece equipment* in the Market Place and Social Network group, *crop advisory* and *local language* from the Information and Education group, and *save field* from the Advanced Technologies group. Overall, appropriate costs and usability significantly influence an agricultural app's success.

Most of the insightful information gleaned from analyzing features came from reviews mentioning cost and ease-of-use as well. Based on the information extracted during this analysis, government agencies or developers who wish to design precision farming mobile apps should consider the following suggestions.

Pertaining to cost:

- Things that are basic and essential for agriculture, like rain fall monitoring, can be enhanced by the convenience that mobile apps provide. It is important to remember that farmers already have tools for those basic needs, whether it be a rain gauge, the internet, or "the old timers at the feed store." Therefore, the cost of these app features should be relatively cheap. As the study conducted by Blasch et al. (2022) points out, farmers' willingness to pay for precision farming technology is based on their cost-benefit estimations.
- Farmers are willing to pay $42 - $60 per year for data management and tracking apps.
- Developers should make clear in app descriptions what is free and what comes at an extra cost. The costs should also not change once implemented. Farmers that had changing costs on their apps felt taken advantage of, especially since app technology can be less accurate than traditional methods.

Pertaining to ease-of-use:

- The user interface should be uncluttered, with buttons consolidated by likeness and labeled not only with text, but with icons for quick interpretation of what each is for.
- Maps and location coordinating tools should be big and readable while mounted on a tractor dashboard.
- Video instructions are helpful for setting up tools such as connecting an external GPS device with an app.
- Local languages are important.
- The agricultural app will be one of many on a phone. It should be considered a tool in a tool belt which is easily closed and reopened and function well when other apps are active simultaneously.

Other suggestions:

- As indicated by the literature and by the reviews analyzed here, sharing information such as maps of areas sprayed, market prices, and knowledge are essential to successful farming. Unfortunately, the sharing features were frequently criticized in

the reviews for not working, so more emphasis should be put on optimizing these tools.

- Specific information about crops that takes into consideration location, crop type, weather, seed time, and many other variables, is more useful than general suggestions.
- In some cases, advanced technology is needed or should be improved. For example, GIS might give farmers better land measurement accuracy than GPS. Also, the AI technology used for identifying plant diseases received only mediocre reviews.

Limitations

Some of the greater limitations to this study pertained to language. Translations did not always carry the meaning from the original version to the English version. This could be due to words translated inaccurately, or because any grammatical or spelling emphasis would have been lost. It could also be the case that some reviewers wrote in English, though it wasn't their first language. These reviewers might not use as much emphasis or slang as someone whose first language is English. Without these types of emphasizes, SentiStrength cannot determine sentiment as well.

Another issue encountered was the repetitive reviews that were collected for BigHaat Smart Farming App. These reviews appeared for the features *agriculture student* and *pay version,* and all gave the same message but phrased slightly differently. The cause of this is uncertain, but it could be due to the app developers paying people to write good reviews with specified compliments to be given. This unfortunately influenced the collocation and topic model generations.

It should be acknowledged that this analysis only included farmers that are already willing and able to try new technologies such as mobile apps. The information collected here doesn't provide insight into how developers can encourage farmers to try precision farming through apps. Improving existing apps will motivate farmers to suggest these tools to their colleagues, which can, over time, influence a larger variety of farmers to try as well.

If this study was conducted again, more consideration would have been put into what types of applications were chosen, instead of focusing on gathering a large number of reviews. The more popular apps did not produce more insightful reviews than the others. The larger app groups, Market Place and Social Network and Information and Education actually produced fewer interesting results than the other two.

Future studies can build off the techniques used in this analysis to examine even more features than what was possible here. Reviews have been shown to provide valuable insight into what makes agricultural apps successful with farmers.

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Statement of Authorship

I hereby confirm and certify that this master thesis is my own work. All ideas and language of others are acknowledged in the text. All references and verbatim extracts are properly quoted and all other sources of information are specifically and clearly designated. I confirm that the digital copy of the master thesis that I submitted on May 5th, 2022, is identical to the printed version I submitted to the Examination Office on May 5th, 2022.

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