School of Electronic Engineering and Computer Science

Final Report

Programme of study:
Computer Science with Management (ITMB)

Project Title: Botanica: A Web Program to Promote Pollination and Biodiversity

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Abstract

Pollination is a key contributing factor to conservation across the globe. In the UK, where much land is used for agriculture, most conservation efforts are beginning to rely on farmers transforming their own land away from crop production, towards biodiversity conservation. However, there are still ways in which biodiversity and conservation goals can be achieved, and that is by targeting landowners with hectares of land that are going unused.

This project introduces Botanica, a platform that leverages the stress of implementing conservation and biodiversity towards any willing landowner, not just farmers. The British government has a bursary already available, the Countryside Stewardship, which pays any landowner that integrates specific plants onto their land with a monetary incentive. The benefits derived from this scheme include additional profit for landowners who were not previously using their land, as well as a benefit to the pollinators whose numbers are dwindling. Botanica is designed to enhance this process by implementing a recommendation algorithm, so the species recommended will flourish on any user's land, thus increasing the success rate of this scheme.

General Terms

ABT – Aichi Biodiversity Targets

AES – Agri-Environment Schemes

AgTech – Agricultural Technology

CRS – Crop Recommendation Systems

CYRS – Crop Yield Recommendation Systems

IOT – Internet of Things

JNCC – Joint Nature Conservation Committee

USDA – United States Department of Agriculture

Contents

Table of Figures

Chapter 1: **Introduction**

1.1 Background

1.1.1 Pollinators and the Countryside Stewardship

Pollinators significantly contribute to biodiversity, food security, and plant reproduction. Due to their populations being negatively impacted by climate change, with 1 in 10 pollinator species threatened with extinction, many countries are beginning to prioritise increasing the population of these endangered species [20], [54].

The Countryside Stewardship has been established by the British government since 1991. Despite this scheme seeing a large increase in recent years, to 32,000 grants in 2023 (an increase of 94% increase from 2020), the main participants are farmers [19]. In 2015, as part of this scheme, the government introduced a Nectar Flower Mix (AB1) option designed to give a monetary incentive for participants to cultivate pollinator-friendly plants on their land [52]. This option, compared to the others, broadens the type of participants that can engage in the scheme, as planting pollinator-friendly species is a simpler task than the alternative options (examples of which include management of historic water meadows, woodland improvement or harvesting cereal) [56].

1.1.2 Importance of Crop Recommendation Systems (CRS)

There is strong evidence to suggest that technology yields new growth in agriculture. According to a McKinsey report from 2020, farmers have started to consult data on an array of variables including soil, crops and weather [16]. By comparing this data to the known optimal conditions for an array of crops, research into crop recommendation systems (CRS) have emerged in recent years [18], [22], [23], [41].

CRS are "computer-based tools that help farmers make informed decisions about which crops to plant" [22]. Originally, recommendations were completed by experts with specialist knowledge, with consultations requiring intense labour and human data analysis – which took a significant amount of money and time to complete [22]. Furthermore, CRS works effectively as the implementation of these recommendations provided by the technology are known to increase crop yields whilst decreasing resource usage [23].

1.2 Problem Statement

As of 2024, there are no applications in place that help to promote onboarding onto the Countryside Stewardship scheme. Additionally, there is no evidence of initiative from the British government in developing an application similar to Botanica. This is possibly due to the declining investment of the UK government into any of the 70 organisations involved in the "recording, researching and conservation of nature in the UK" [4].

The Joint Nature Conservation Committee (JNCC), the single statutory nature advisor to England, Wales, Scotland and Northern Ireland, claims that any improvement of biodiversity "has often been the product of targeted partnerships" [3]. Therefore, there is a need for a software that targets and assists individual landowners in partaking in the biodiversity schemes offered to British citizens.

As for CRS, a few beta applications have been released that include the relevant parameters (i.e., soil acidity, soil type, etc.), but none that meet the requirements for users to store their receipts for evidence for reimbursement or forecast profit.

As a result of these issues, there is a need for an application that targets landowners and has tools to allow users to store their evidence in one place.

1.3 Aim

The aim of this project is to create a web application named Botanica. Botanica is designed for landowners interested in leveraging their land to support environmental conservation by planting species that foster biodiversity and benefit pollinators. As a government scheme, the "Countryside Stewardship", has already been established since 1991, the aim of this application is to encourage greater participation from the British population [56]. Due to continuous research in the promotion of pollinators, the species that should be planted to support this cause, within the UK, have already been determined by Natural England [3]. Therefore, by utilising user input and an advanced algorithm, Botanica can suggest the top six species that would thrive under the natural conditions of the user's land. In addition to this, due to the application being given the amount of the user's available land, Botanica can calculate the forecast earnings for whichever user is participating in the scheme.

1.4 Objectives

The proposed solution for the problem is Botanica, a web application with an implemented species recommendation algorithm. Botanica has the additional features of forecast profit and storing evidence. The objectives of the project are:

- Design a web application specifically for landowners. The system should be simple, intuitive, and not require the use of training or tutorials.
- Undergo user research via a pilot user study of individuals that own a large plot of land (>2He) and use the results to identify requirements for the application.
- Design a user interface that is intuitive to landowners, whilst ensuring that there is not information overload on the interface (i.e., not excessive explanation on how to use the available functions). Familiar functions such as sign up, login should be included.
- Develop an algorithm that will recommend the top three government-specified species that are most suited to the conditions of the user's land. The algorithm should also recommend another three non-government-specified species that should be included in the flower mix (the flower mix cannot be entirely government-specified, according to the Countryside Stewardship policy).
- The algorithm should generate the forecasted profit for users if they were to engage in the scheme.
- Create a web application that will record data input including user receipts.
- Allow users to upload, view, and delete their receipts. This allows for a digital copy of records, which can be used as evidence for reimbursement from the British government.

1.5 Research Questions

Given the introduction of new technologies into agriculture, a need to research their benefits was created. Furthermore, there is a need to understand the stress farmers are currently under to transform their land away from agriculture. As a result, the following questions should be addressed:

1. What are the benefits of technology in agriculture?
2. What are crop recommendation algorithms and how do they benefit agriculture?
3. Why is there a need for conservation in the UK?

1.6 Report Structure

Chapter 2 will consist of a domain analysis of CRS, as well as land management systems (LMS). Both are covered as features included in this project are seen between both CRS and LMS, i.e., not all the features included can be found in one domain. After this analysis, literature regarding the benefits of automation, connectivity and CRS in agriculture will be explored, followed by a review of current methods the UK uses to implement biodiversity.

Chapter 3 includes the results of the user-study, which will be followed by requirements analysis, including both functional, non-functional, and optional requirements.

Chapter 4 discusses the system design of Botanica and explains its functionalities.

Chapter 5 includes the implementation of Botanica, including any libraries or data that have been utilised.

Chapter 6 covers unit and user testing to evaluate the applications usability.

Chapter 7 includes the results of this application, and an evaluation of its effectiveness. The evaluation will also refer to research covered in previous chapters, as well as the requirements section to assess if all requirements were met.

Chapter 8 includes the conclusion of the report and discusses any work for the future.

Chapter 2: **Research**

Research for this project began with a review of literature to understand the current implementation of technology in agriculture, and the resulting benefits of this technology to farmers and the wider population. This will be followed by an analysis of software currently available in the agricultural technology (AgTech) market.

2.1 Literature Review

The literature review will first introduce the concept of technology in agriculture. Next, the prevalent features this technology includes being automation, connectivity, and suggestion algorithms will be explored. Following this, the need for conservation will be examined.

2.1.1 Background of Technology in Agriculture

There is a general understanding that developments in technology will enhance many different industries [16]. Within the last decade, agriculture has been one industry that has implemented and benefitted from new technologies, with this crossover between agriculture and technology being commonly referred to as "AgTech".

Initial technologies within the AgTech market focused on implementing automation where possible. In more recent years (2018 onwards), the focus has shifted to implementing mobile technology to keep farmers connected to their land, even when they are not in proximity. These implementations have been accomplished through the use of 3G [16]. Finally, most recent developments in AgTech (2020 onwards) include high-end data analytics, such as financial reporting and yield analysis. As of 2021, the World Economic Forum, a not-for-profit organisation with a goal of creating "meaningful connections between stakeholders" claimed that "modern farming is as much about data as digging" [25], [26]. This claim can be supported by the expected market size of big data analytics in agriculture reaching $1.7Bn by 2031 [27].

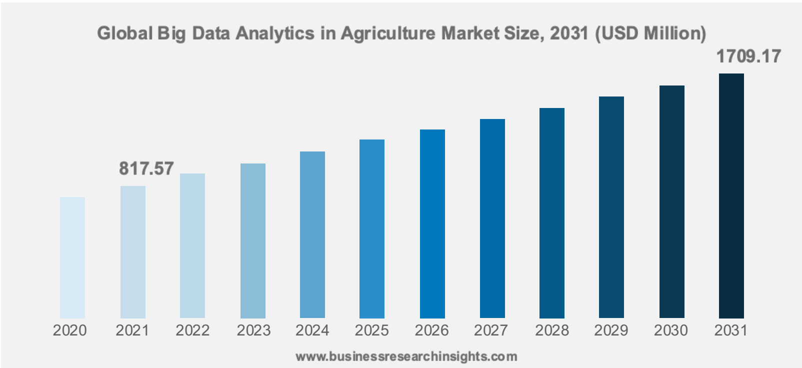


Figure 1 The projected growth of Big Data Analytics in Agriculture, globally [27]

In 2018, the United States Department of Agriculture (USDA) introduced a bill named the Agriculture Improvement Act, which set in a motion of applying new technology into the agriculture industry in numerous ways including automation and data analysis. The resulting investment into both automation and data analysis by the USDA reflect their importance within the industry, with automation research being funded by over $20 million, and data analysis over $30 million [figure 2].

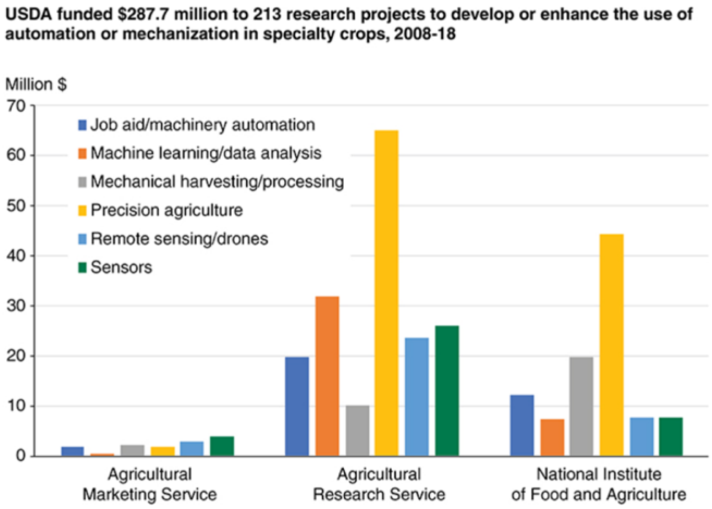


Figure 2 Distribution of USDA investment into different technologies [57]

On the contrary, since the introduction of AgTech, many farmers are hesitant to switch to tech tools, and those that do "struggle with the software and a flood of data from their farms" [45]. A survey from the Wall Street Journal highlighted that farmers found the first generation AgTech tools that are being used lack speed and have complex user interfaces [45]. This reluctance becomes more understandable given that only 15% of American farms have substantial internet access, and many AgTech software rely on this access [47].

2.1.2 Automation in Agriculture

One example of AgTech products are Farm Management Information Systems (FMIS). FMIS are used to collect, aggregate, and import data related to farming activities. These processes, which are usually carried out manually by farm owners, have become automated due to the time-consuming nature of them, which "farmers are reluctant to perform" [10]. As a result, the benefit of this type of software to its clientele is that it allows users to spend more time on their farm rather than on administrative tasks.

Automation via farm management tools also reduces the barrier of entry into the farming industry. The introduction of high-tech farm management tools has allowed for younger generations to enter into the market, as there is less need for specialist farm knowledge to run a farm (due to the existence of these tools) [14]. This is particularly important given the recent decreased interest in farming and "aging farmer population" [15]. In figures 3 and 4 below, both the age distribution of farmers and the prevalence of technology usage across different ages of farmers can be examined.

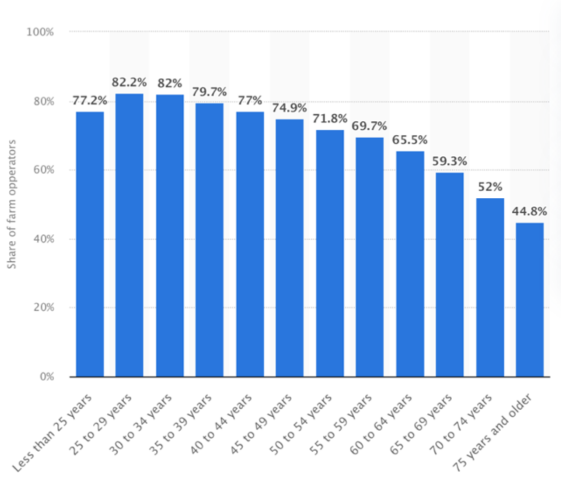


Figure 3 Distribution of Tech Users within Farming Across Age Groups [43]

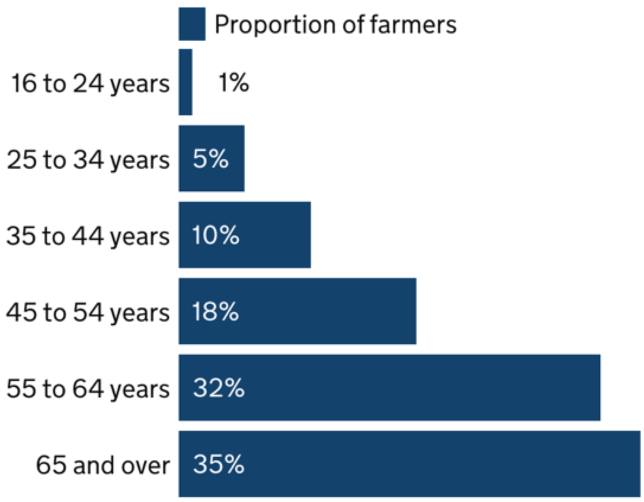


Figure 4 Distribution of Farmers Across Each Age Group [42]

It can be deduced that over half of farmers in the UK today are over 50 years old, and that younger farmers are much more likely to use technology in their work. This information suggests that there is increased adoption of technology in agriculture in newer generations. This adoption is likely to continue, and spread into the older age groups over time (i.e., as the younger generation ages), due to the current younger generation maintaining both knowledge and familiarity with the technology that has been implemented today.

By analysing the potential for FMIS and the dispersal of age groups using technology on their farm, it can be deduced that the more tasks that become automated by AgTech, the higher the possibility for farming to become more inclusive to younger generations.

A final benefit to farmers from automation is that automating tasks for farm management reduces the need for labour. With labour wages growing at a faster rate than previous years [figure 5], FMIS helps to "mitigate the impact of labour shortages and higher costs" [45]. It should be considered that this profitability should be measured over a longer period of time, considering the initial costs of implementation of this technology being high.

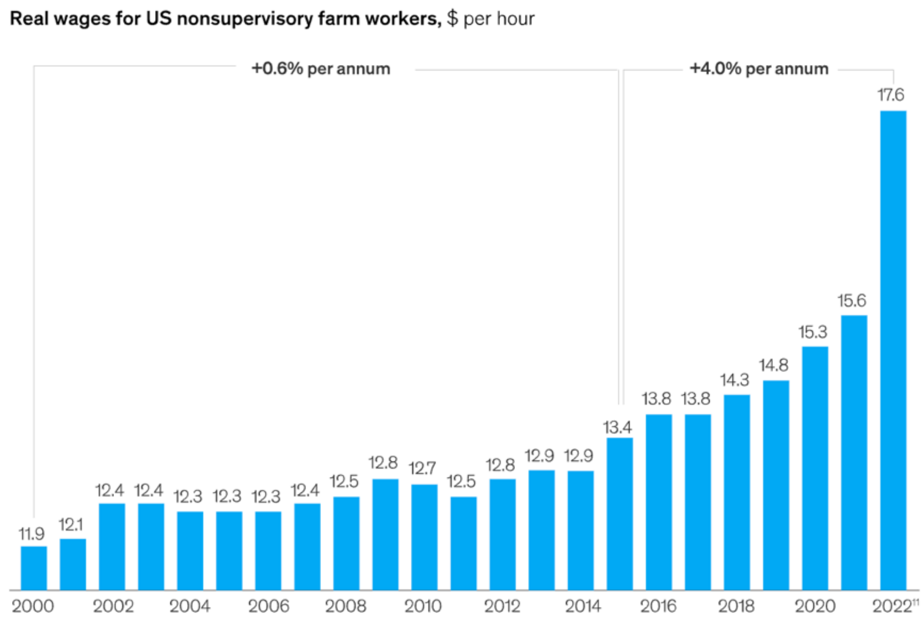


Figure 5 Chart of Increasing Labour Wages in Farming [40]

2.1.3 Connectivity in Agriculture

Connectivity is the core of the Internet of things, as it refers to the ability of different technologies to connect to one another. This can include different computers, systems, devices, or programs [38], [39]. Connectivity in agriculture allows for variables of crops and livestock to be monitored from afar, with connectivity generally being accomplished via hardware planted throughout the farmland connecting to software on the farmers computer. With better knowledge of the variables being collected, such as soil health and water level, farmers are able to make more informed decisions. This introduces the possibility to "increase yields [and] improve the efficiency of water" [16].

However, despite one of the main problems faced by British farmers being soil management (26%) [17], the current soil mapping tools available in the UK are only used by 29% farmers [12]. It appears that despite the potential of connectivity in agriculture, few farmers have accessed the advanced technology. This issue can possibly be attributed to limited access, with some software's alone (i.e., without the necessary hardware) costing thousands. Alongside a considerable cost, many of these tools still require large amounts of manual input before becoming useful.

2.1.4 Data Analysis and Crop Recommendation Systems

Data analytics are responsible for “improv[ing] quality and quantity of agricultural production” and reducing crop waste. This is done through implementing better monitors, gathering more precise data, and applying innovative processing functions to the collected data [14]. Regarding data collection, the agriculture industry has seen a large increase in data generation, and from figure 6 below, is predicted to generate over four million data points per day by the year 2034 [44].

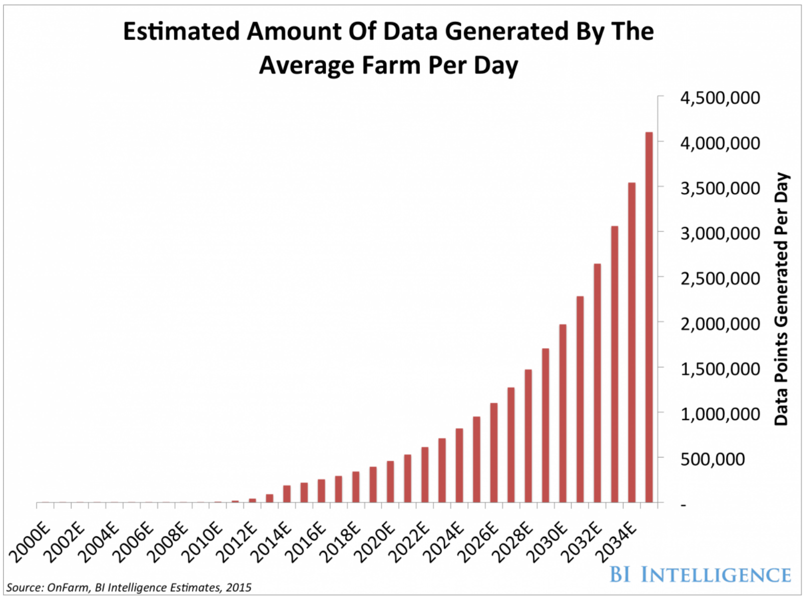


Figure 6 Estimated Generation of Data in Farming [44]

Forecasting is a type of data analytic tool that “predicts […] important parameters”, which inform farmers decision-making processes [14]. For example, the results of forecasting can help farmers make decisions on crop selection (which subsequently increases yield), or lead farmers to reduce their use of water or fertilisers. Therefore, as AgTech reduces the risk of information gaps, users are now able to make better informed decisions which can benefit the user monetarily, and the environment by reduced consumption of synthetic fertilisers [53].

Crop recommendation systems (CRS) fall under the branch of data analytics and are different to crop yield recommendation systems (CYRS), the latter of which identifies a species of plant based on its yield. Instead, CRS collects the levels of different parameters of farmers land and applies an algorithm. However, there is a discrepancy between systems due to their varying dependencies on alternative parameters. For example, the Devang Patel Institute of Advance Technology and Research Charotar University of Science and Technology (CHARUSAT) developed an algorithm that considered levels of nitrogen, phosphorous and potassium, whereas systems in the CRS market such as FarmEasy did not (i.e., only include temperature, rainfall, and soil type in analysis) [18], [41].

Nevertheless, by processing precise data: accurate suggestions can be accomplished. This is particularly useful in countries such as India, where farmers “wait for the weather to match their farming practices”. With the knowledge from recommendations, the process of moving towards adjusting their crop to complement the natural conditions of the land becomes more streamlined [41].

However, in the United States, only “one quarter of farms” are currently turning aggregated data into “valuable, actionable insights” [16]. Some tools used on American farms automatically collect data from sensor equipment, but many other tools require manual input. This leaves farmers feeling paralysed when attempting to analyse the data collected and have difficulties drawing conclusions that give useful insight [45].

2.1.5 The Need for Conservation in the UK

The United Kingdom consistently ranks at bottom of the G7 in survivability rates of biodiversity. Tony Juniper, the Chair of Natural England, the governments “advisor for the natural environment in England” described the UK as being a “nature-depleted nation” [11], [50]. As of 2023, 15% of species in the UK are threatened by extinction and a decline of 60% has been calculated in British “priority species” [3].

Currently, the United Kingdom is failing to achieve 14 of the 20 Aichi Biodiversity Targets (ABT) they promised to meet by 2020. This agreement was made in 2010 by 196 countries and set “to halt the loss of biodiversity globally” [3],[96]. As of 2023, the UK is still failing to deliver on 14 of the 20 targets it agreed to. This outcome is expected given that public expenditure on biodiversity has decreased from by 33% from 2015 to 2019 [3]. This evidence suggests that conservation of biodiversity ranks low on the British government’s priority list, despite a pressing need to meet the ABTs.

The current schemes in place only target those in the agriculture industry. Agri-environment schemes are programmes set by governments to aid farmers in managing their land and promoting biodiversity in an environmentally-friendly way [54]. However, the success of these schemes has been measured and either maintains or has little to no effect on plant biodiversity. This is perhaps due to farms already being plant diverse, and so a transformation of land into planting other species has little to no effect on the variety [51]. Therefore, there is a strong argument to suggest that transforming land used for agriculture does not have a net positive impact on biodiversity.

For the reasons aforementioned, it is crucial that more technological methods that are more efficient and effective than those in place today are developed to promote conservation of biodiversity. Most importantly, these methods should be accessible by the wider population to have the highest impact.

2.1.6 Summary and Analysis

Agricultural technology is a growing market. Its benefits derived from precision and data analytics include increasing yields, sustainability and making harvests more successful and environmentally friendly. Due to these benefits, many governments are promoting the introduction of more technology into agriculture through funded research and bursaries.

On the other hand, governments across the globe are under pressure to meet the demand of the conservation efforts required to help the environment. Much of this pressure is then levied onto farmers, who are then expected to transform their land away from agriculture to the less profitable conservation efforts. This causes stress to farmers due to reduced yields and so loss of profit.

As a result, there is a need for an application that implements the same technologies as those prevalent in agriculture but are aimed at those landowners that are not utilising their land for agriculture or biodiversity. Thus, stress is leveraged away from farmers, conservation efforts are closer to being met, and the schemes are more likely to be successful given the data analytics underwent.

2.2 Domain Analysis

To understand the industry that the application will best fit into, a comprehensive domain analysis is conducted on crop recommendation and land management applications within the AgTech sector. This is to ensure the application does not repeat what is already available to consumers in this market and does not make similar mistakes that producers in the market have made already.

2.2.1 FarmEasy

FarmEasy is an advising application that utilises machine learning. FarmEasy's target market are farmers, and its aim is to "mitigate the agrarian crisis" [18]. Parameters that are considered include crop name, sowing time, region, temperature, rainfall, soil acidity and soil type. The services offered include recommendations of best crops to plant, information on the crops, and predictions. FarmEasy particularly supports the decision-making process farmers undergo before cultivation.

Although FarmEasy uses a large dataset and advanced algorithm, the platform does not provide any other services. Features such as storing the information are of high desirability in the AgTech market, but have not been included in this application.

2.2.2 Sum-IT

Sum-IT is a land management application that is provided over desktop and smartphone. It is aimed towards farm owners looking to fully integrate all of their farm-related data into "one hassle-free place" [55]. Although it provides other features including dairy herd management as well as beef and sheep management, the focus of this analysis will be of its "Total Field & Crop" (TFC) Software.

The benefit of the TFC software package is that it allows users to view records of single farm fields, search field names and add tasks with due dates. However, at this point in time, it is only available on android devices, which is very limiting considering that iOS holds around 51% of the market share for mobile operating systems whereas Android holds around 49% [9]. Furthermore, in regards to user experience, Sum-ITs user interface could be considered slightly outdated due to its use of bold colours and large buttons. Finally, Sum-IT offers no suggestions to the user of any kind (i.e., no crop suggestion or livestock recommendation). The software simply displays the user's data in one place or as individual reports. Although this gives the user perfect knowledge to support any decisions that are made by the user, it is simply automating tasks that were already being carried out. Essentially, there is no innovation or introduction of any new ideas [10].

2.2.3 Figured

Figured is a financial management software for farmers. Figured's aim is to allow users to instantly access farm-related financial data to aid in the decision-making process. As its key features is automating and enhancing financing, Figured does offer a wide range of forecasting operations, including "P&L, cash flow and balance sheet forecasting" [11]. Figured also offers a breakdown of estimated income per product (i.e., wheat grain, etc.), using yield per hectare compared to the estimated market price. Additionally, Figured's use of cloud technology allows users to generate and access up-to-date report whilst also enabling users to work together on documents in real-time. Finally, as for its user interface, Figured has kept minimal in its display, with a consistent dark blue theme and use of bootstrap.

Whilst fully integrated with accounting software, it appears the scope for Figured is too large, or limits itself to large-scale farms. This in turn reduces the pool of consumers the software is applicable to and may further cause users to encounter a learning curve, as the software is difficult to use without training.

2.2.4 AgriWebb

AgriWebb is a livestock management software. It is accessible via a web browser, or as an application available on iOS or Android devices, therefore making it available on tablets also. The services AgriWebb provides includes farm mapping, task management, calendars, and planning. It is similar to both Sum-IT and Figured aforementioned, with selected features from each one. For example, it can upload data to the cloud similar to Sum-IT and provides a breakdown of statistics per field similar to Figured. However, AgriWebb's additional benefit compared to other software's is that it is available offline, as well as on both iOS and Android [12].

However, it is also similar to Sum-IT and Figured as it does not include a crop recommendation system. Furthermore, AgriWebb does not include the benefits of data forecasting, as it only has basic data analytic tools (i.e., not as advanced as Figured).

2.2.5 Tables

Table 1 – the advantages and disadvantages of each of the software's of interest in the AgTech domain:

Software	Advantages	Disadvantages
FarmEasy	- Recommendation algorithm using machine learning - Algorithm utilises large data set - Simplistic user interface, easy to use	- Only useful to farmers - Does not store any kind of record
Sum-IT	- Generates reports to help with agriculture-related decisions - Stores data on soil analysis	- Only useful to farmers - Bold buttons and bright colours - Only generates reports from data - No crop recommendation
Figured	- Generates reports to help agriculture-related decision-making process	- Only useful to farmers - No crop recommendation
AgriWebb	- Works offline - Farm mapping and distribution of crops and livestock - Inventory management - Includes personalised "sustainability story"	- Only useful to farmers - Mainly a livestock management tool - No profit forecast, only profit analysis tools - No crop recommendation

Table 2: Each software of interest and its included features in comparison to Botanica:

Software	Recommendation Algorithm	Profit Forecast	Desktop and Smartphone	Stores Records	Modern User Interface
Botanica	✓	✓	✓	✓	✓
FarmEasy	✓		✓		✓
Sum-IT			✓	✓	
Figured		✓	✓	✓	✓
AgriWebb			✓	✓	✓

2.2.6 Summary and Analysis

In summary of the domain analysis, it appears the most prevalent features within the AgTech market including storing digital records, task management via mobile and forecasting an array of land-related parameters. These features are possible due the introduction of automation, connectivity, and data analytic software into agriculture.

An additional attribute that is common amongst most AgTech interfaces, (disregarding Sum-IT) is the designs simplicity. Given the sophisticated nature of the features included in the software's, it appears necessary to implement modern user interfaces that promote full usability – especially to older generations who have previously carried out these processes manually.

Chapter 3: **Requirements**

Requirements are set before a system is developed to ensure a clear goal and scope of the application.

3.1 Functional Requirements

Functional requirements "describe the services a system to provide" as well as "how the system will react to its inputs" [7].

3.1.1 Core

1. The application must allow users to create an account with a username and password.
2. The application must allow users to log in with their username and password.
3. The application must allow users to input their lands soil acidity.
4. The application must allow users to input their land soil type.
5. The application must allow users to input average temperature in their area.
6. The application must allow users to input how much of their land they wish to use.
7. The application must allow users to upload their receipts.
8. Users must be able to view their records of receipts.
9. The application must run on web using the Django and python programming language.
10. The application must give six plant species suggestions, with three being government-specified, and the other three being native species to Britain.
11. The application should generate forecast profit from the grant given the users input.

3.1.2 Optional

1. The application should allow users to upload their records of other photographic evidence.
2. The application must allow users to view their records of other photographic evidence.
3. The application should store records of user's receipts and other photographic evidence as JPEGs.

3.2 Non-Functional Requirements

Non-functional requirements are used 'to drive the operational aspects' of the system [8].

3.2.1 Core

1. The application must be built using a Django web framework.
2. The application will run on Google Chrome, Firefox and Safari.
3. The python and Django code must be well-documented.
4. The suggestion algorithm process should take a maximum of thirty seconds to complete; this includes both the entering of user input and generation of the suggestion.
5. The system must store user passwords securely with Django's hashed passwords.
6. The system must have labelled buttons.

3.2.2 Optional

1. The interface should follow a colour theme of no more than 4 colours, specifically: #f7f72, #f86f7c, #2f4550 and #fff
2. The interface should use the same font on each page.
3. Different pages of the interface should have little to no deviation in design.
4. The interface should have a welcome message upon the user logging in.

Chapter 4: **Design**

This chapter will provide an overview to how the requirements impacted the design of Botanica, as well as how the system functions.

4.1 System Architecture

Botanica utilises Django, an open-source web framework [29]. The system uses the model, form, view, and template components:

1. **Model**: a source of information about the systems data, containing expected fields and behaviours of the data that is being stored [30]. In Botanica, the models include one for plants and one for receipts.
2. **Forms**: Django forms allow users to input information into the system. In the form class, it is determined what type of information is expected by the user and so accepted by the system [31]. In this projects system, there are forms for uploading receipts, selecting options as well as authenticating and registering as a user.
3. **Views**: are functions written in Python. Views can, for example, manipulate data or render different pages within the application. Within this application there are a variety of views including the suggestion algorithm based on user input, login users and sign users up [32].
4. **Templates**: are text files. In this case, all templates are HTML files. The templates are the foundations for the user interface, as they contain most, if not all views. They are rendered for the users, and allow them to input data into the forms and switch between other HTML files available on the web application [33].

4.2 System Structure

This is a Django project, with a single application named “napp”. This application contains two models, alongside several views and the appropriate number of templates to support this service. It covers:

1. Signing up
2. Logging in
3. Letting users input their selection of data
4. Letting users upload their receipts and other evidence
5. Letting users view their uploaded receipts

6. Letting users delete their receipts
7. Logging out
8. Algorithm for suggesting plant species

The user perspectives for the features mentioned above can be found below.

4.3 User Perspective

Figure 7 below depicts the expected behaviour of the system from the users point of view. All functional requirements aforementioned in chapter 3 are included, with the relationships between each of the requirements, as well as the relationship between requirements and users being shown.

4.3.1 Botanica Use Case Diagram

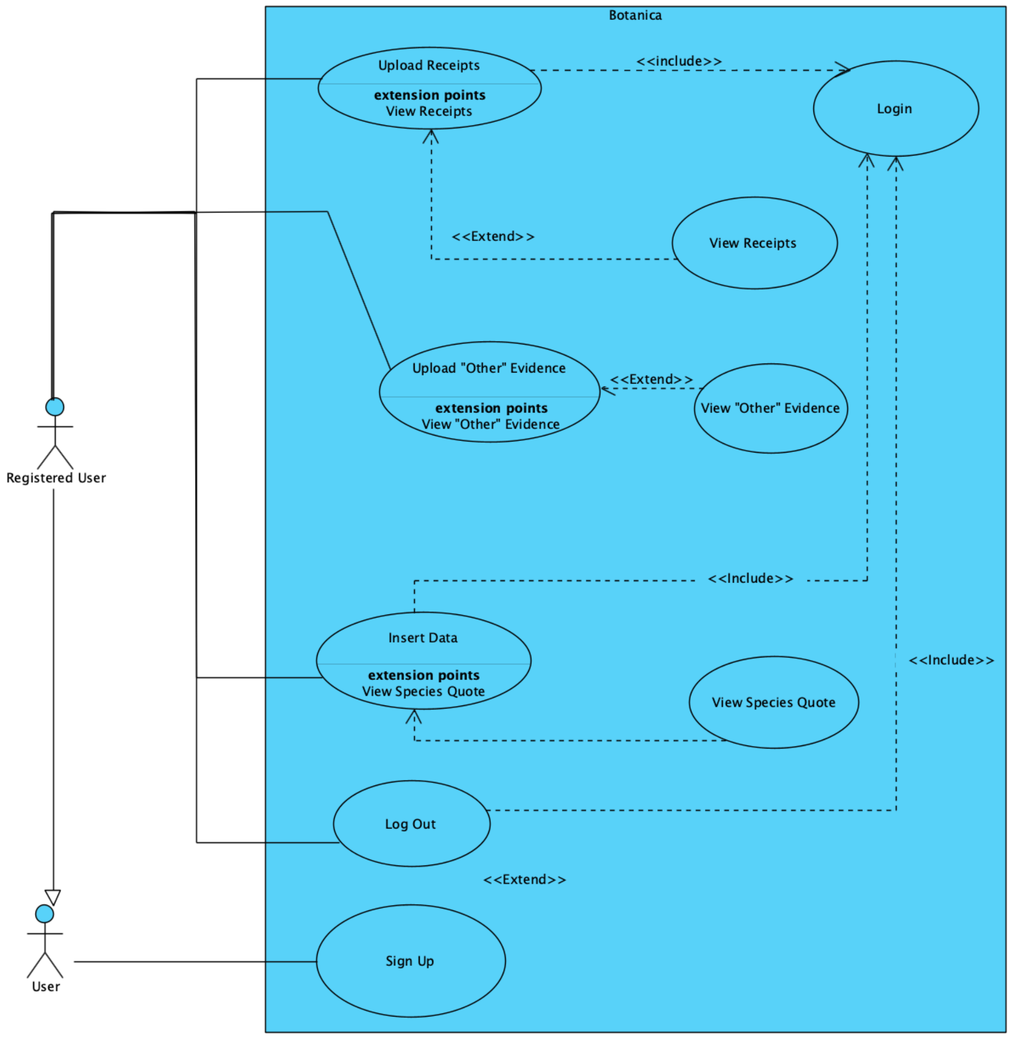


Figure 7 Use Case Diagram

4.3.2 Breakdown of Botanica Use Case Diagram

There are two actors:

1. **User**: a user of the system. Can only use the sign up function.
2. **Registered User**: a user of the system with a Botanica account. Has already created an account so can log in and trigger all use cases.

4.4 Development Methodology

The development of Botanica mostly followed an agile methodology, in particular: agile iterations. By developing in iterations, the project allowed for any changes in requirements. Furthermore, by having small iterations, it was possible to focus on the delivery of features gradually, ensuring their usability and functionality before moving onto the next iteration.

Iterations were planned to last between 7 and 9 days. This resulted in the prototype for the main feature, the plant recommendation algorithm, being useable early in the development process. Other features such as sign up, log in and upload evidence were added subsequently.

The later iterations focused on the styling of Botanica, as well as testing each of the functions. Using agile iterations allowed for some scope creep, where system requirements increase throughout the development of a system [3[475]. At the end of every iteration, current requirements and potential additional requirements were reflected on. This did allow for some additional features, such as uploading other evidence, to be implemented closer to the end of the project lifecycle.

Chapter 5: **Implementation**

The implementation of the Botanica system will be described within this chapter. The Django application built, as well as how the suggestion algorithm was established will be discussed.

5.1 Frameworks and Libraries

5.1.1 Django

Botanica was built using Django, a high-level web framework that utilises Python [29]. Django was selected due to previous experience building web applications with this framework, and for its security with user authentication. This includes its hashing of user passwords, and easily customisable authentication forms.

Django also allows models to be built. These models, which are classes written in Python, represent database tables. For example, the Plant model was created with three attributes, each of which were individualised for every instance of Plant. Implementation was completed with ease, due to the removal of the need to write any SQL scripts.

Django's test framework allowed for unit tests to be written and carried out with ease, and the development server accessed by the manage.py runserver command was a key tool when experimenting with different CSS designs.

5.1.2 CSS

The interface is styled using Cascading Style Sheets (CSS). This was also selected due to previous experience, and allowed for much flexibility when it came to designing the user interface. Using CSS allowed for implementation of the non-functional requirement of having a colour theme.

5.2 The Django App

The Django app contains a number of different functions to support the services available in Botanica. Each function is mapped to one or more correlating template.

5.2.1 Signup and Login

Users were authenticated using a custom login that required a username and password. This custom login is based on Django's default requirements but made custom by only requiring two fields. The requirements for signing up were reduced, i.e., no email was required, but the system did only accept passwords that met the authentication password validator rules. These rules include a similarity validation (how similar is it to the username), minimum length (8 characters), common words (and therefore guessable passwords), and finally a numeric validator that ensures passwords contain at minimum, one numeric character.

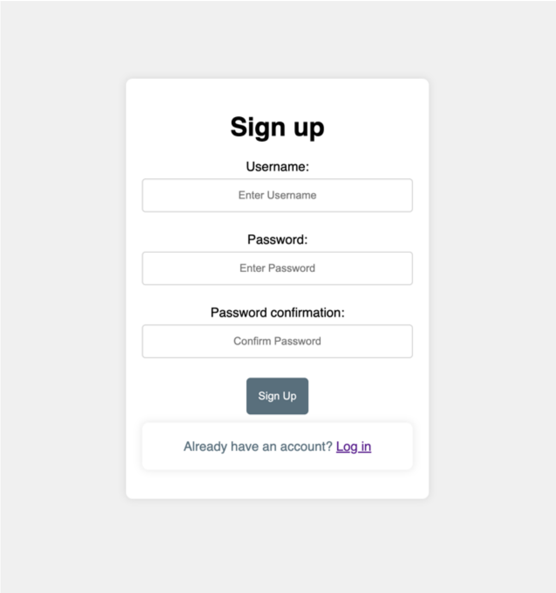


Figure 8 Screen Capture Taken From Botanica Sign Up Page

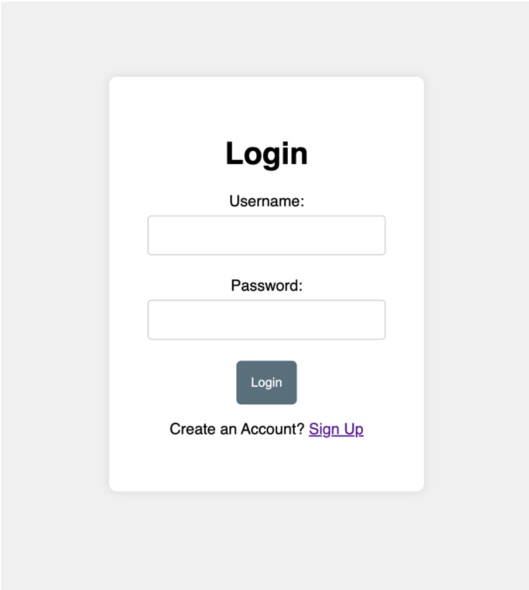


Figure 9 Screen Capture from Botanica Login Page

5.2.2 Input and Result

The input requires four parameters from the user. The user must select one option for 3 parameters, and finally enter a number. The options are for soil tyle, soil acidity and average temperature. The number input represents the amount of hectares the user has. As this is individual to the user, unlike the other options, the field is an 'IntegerField', not a 'ChoiceField'.

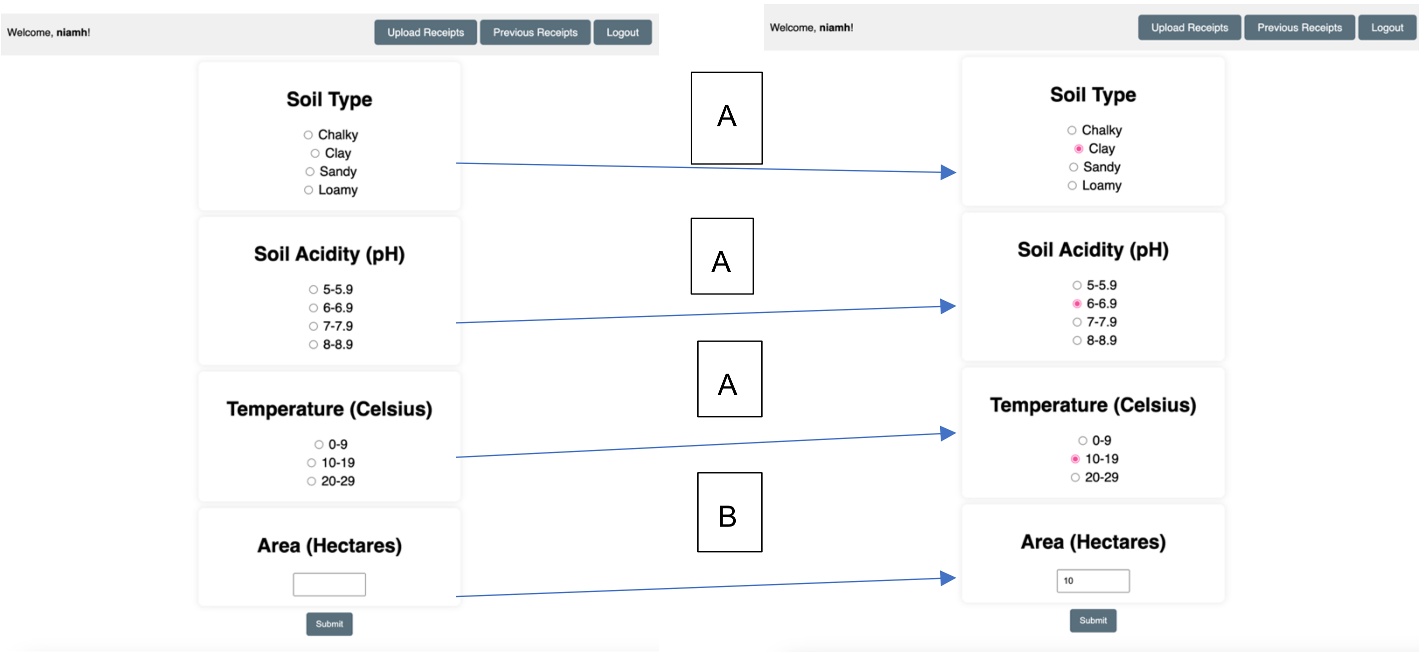


Figure 11 Screen Capture Taken from Input Page

Figure 10 Input Form Filled In

Letter	Field
A	ChoiceField
B	IntegerField

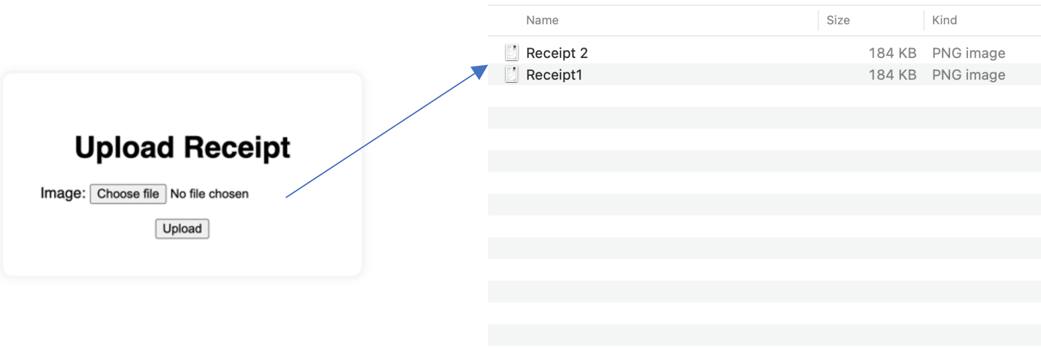
Figure 12 Table Depicting Which Field the Form Requires

The results from applying the recommendation algorithm to the user input are displayed on a separate page after pressing the "submit" button. The results are separated into two distinct categories; government-specified and non-government specified. The results page is discussed in further detail under the recommendation algorithm (page 30). The reason these recommendations are separated is due to the government scheme requiring a mix of flowers being implemented into the user's land, a "seed mix", rather than entirely government specified, or entirely non-government specified [19]. This ensures the maximum variability between users, and increased variability essentially equals increased biodiversity.

5.2.3 Upload, View and Delete Receipts

In order to keep digital receipts that are required for reimbursement, users can upload image files of their evidence to the platform. Users can only upload a specified array of types of images, including JPEG and PNG. Image files of 2.5mb. During user testing, there were no cases where an image file was larger than 2.5mb, but if desired, 'file_upload_max_memory_size' could be altered in the settings python file.

Figure 13 Screen Capture Taken From Upload Receipt Page



Once uploaded, users can view their receipts under the previous receipts template. All images have a set width as to give a more uniform design, and are ordered from least to most recently:

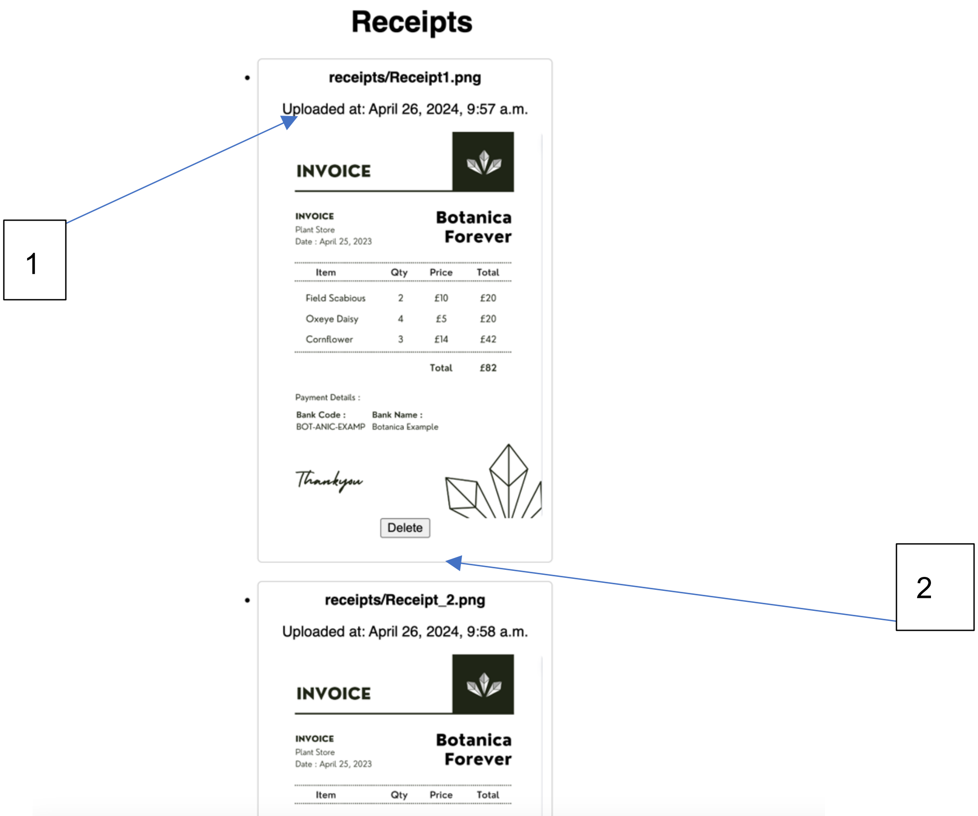


Figure 14 Screen Capture Taken from View Receipts Page

Number	Description
1	Information regarding date and time displayed to the user.
2	Option to delete the receipt.

Figure 15 Table Describing Aspects of the Receipt Object

5.3 The Recommendation Algorithm

5.3.1 Dataset

The dataset for the optimal conditions for the species selected was derived from many data sources and amalgamated into one final table. This was referred to when designing the algorithm.

5.3.2 Algorithm

The suggestion is split between two algorithms. One is used for government specified species, and the other for non-government-specified species. Each of the algorithms begin by cleansing data collected from user input, and temporarily stores the input as a local variable. Next, between four or five species (depending on the algorithm) are presented with their corresponding soil acidity, soil type and optimal temperature.

Using a scoring mechanism, compatibility of species are determined by appointing points if the species optimal conditions match the user's input. If one of the user's inputs matches one of the optimal conditions for a species, one point is added to this species "points". If two inputs match, then two points are added, and so on.

After scoring is complete, each algorithm identifies which plants had the most points (and thus the most compatible), and provides the top three species with the most points. Finally, these results are parsed to a template page which renders them in a more readable format for the user. Each algorithm result is represented in a different box, with clarifying information for the user to read above. The last box represents the amount of hectares input by the user, multiplied by the current amount offered by the British government per hectare as of 2024 [52].

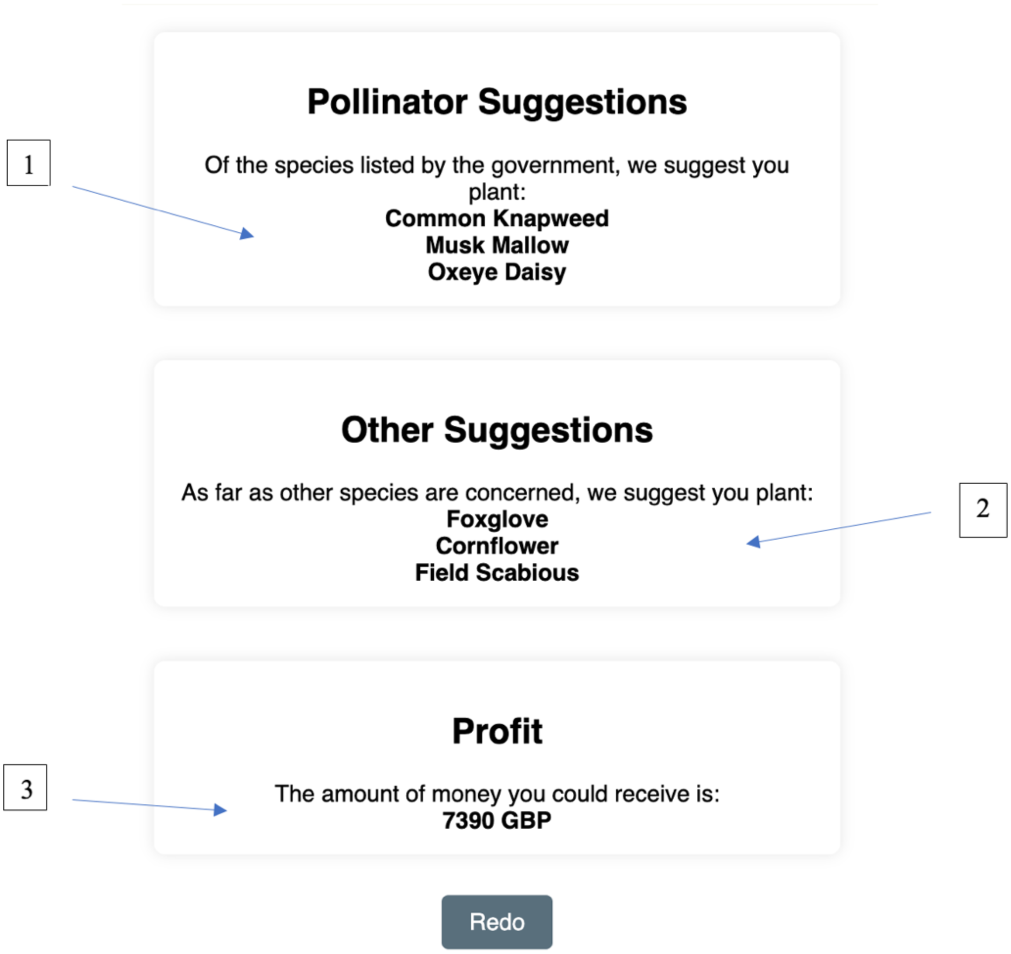


Figure 16 Screen Capture taken from the Suggestion Page

Number	Description
1	Results of comparing user input to species requested by the government.
2	Results of comparing user input to other native species in the UK.
3	The profit generated given the user input of area of hectares possessed.

Figure 17 Table Describing Aspects of the Recommendation Function

Chapter 6: **Testing**

6.1 Unit Testing

Unit testing is used to check pieces of code to ensure their delivery of expected behaviours. These pieces of code can be individual or grouped together as a unit based on their functionality [36]. Unit tests are important during the development of any software system, and "often [grow] as new functionality is introduced to the system" [37].

6.1.1 Method

The application has a file named 'tests.py'. In this file, test cases are written in python, and test views in several ways to ensure they given the expected results given a variety of different behaviours. Tests are grouped together under classes to promote readability and organisation. Therefore, for a function like uploading the receipt, there is one class containing several tests. This arrangement also allows for selective execution, which was particularly useful after completing iterations to ensure full usability before moving onto the next iteration.

Given that many of the functions in the system require the user to be authenticated, in many classes there is an established dummy user. This introduced several authentication tests, all of which passed as expected.

In other cases, where dummy data was required for input validation, data was either manually selected or left empty (i.e., invalid). The most extensive testing for input validation was carried out on the logging in, signing up and the recommendation views.

6.1.2 Results and Analysis

6.1.2.1 Sign up, Login Authentication and Logging Out

4/4 tests passed for the custom ***signup*** view. Signing up only requires a username and password. The success of these tests verifies that an account is created, the user is redirected to the login page if sign up is successful, and that an unregistered user cannot create an account with an existing username.

2/2 tests passed for the custom ***login*** view. By passing these tests, it is verified that any registered user is able to log into the system, given they have created an account in the past. This allows them to view their own receipts, upload their own receipts, or delete their own receipts.

2/2 tests passed for the ***log out*** function. The tests verified that the system gives the expected behaviour (i.e., redirecting to the log in page) once a user has logged out.

6.1.2.2 User Parameters and the Recommendation Algorithm

4/4 tests passed for ***user input*** of data for the recommendation algorithm to use. This meant that all inputs into the form were dealt with correctly, and all expected fields were filled.

2/2 tests passed for the ***recommendation algorithm***. Testing involved verifying that expected species were included in the suggestion, as well as those who did not match the environment not being incorrectly suggested.

6.1.2.3 Upload and Delete Receipts

3/3 tests for ***uploading receipts*** worked. This verifies that users can upload receipts, they are redirected to the correct page, and if the form is invalid, the same page is rendered so the upload can be redone.

3/3 tests passed for ***deleting a receipt***. This ensures that receipts are deleted by the user, can only be deleted with authentication, and no user can delete another users receipt.

6.1.3 Testing

Django's database testing was used, to mimic the data that the application deals with. Therefore, each class was based on Django's TestCase class ,which is itself a subclass of Django's UnitTest [48].

To run tests, the following command was used:

```
python manage.py test
```

There was no need to specify the application "napp", as Django automatically looks for files with the prefix "test_" in the project.

From running this command, all tests are completed successfully with a final OK status.

6.2 User Testing

Five anonymous users were asked to test Botanica and provide feedback. Feedback can include comments on usability, functionality, or design. The data, similar to the users, were also anonymously collected.

User testing unveiled some difficulties with the user interface, which resulted in some minor changes to implementation and design.

6.2.1 Method

A brief introduction to Botanica and its aim were given to participants, followed by a ten-minute window to explore the application. Testing was done on an individual basis, rather than as a group. Users were asked to sign up for an account, login, find out using the recommendation algorithm which species they should plant, store an image of a dummy receipt, and a dummy photo, as well as deleting any of their entries of photographic evidence. There was no order given in which these tasks should be carried out, only that they need be completed. No further information was given to the users, which was done in order to receive as unbiased feedback as possible.

After the tasks were complete, users were asked to rate usability, feature relevance and design on a scale of one to five for quantitative feedback. Finally, any additional comments could be made through an anonymous online form.

6.2.2 Results and Analysis

A few issues were picked up during user testing. There was some difficulty signing up for Botanica, with two of the three testers misinterpreting the rules for possible passwords. Upon clarification, users were able to complete their sign-up task.

One other issue was that photos were taken on an iPhone. Generally, iPhones store images as HEIC type files, which are not currently accepted by the Django 'ImageField'. Therefore, many users had to convert the images of their receipts into JPEGS or PNGS before uploading. Perhaps implementing a photo taking feature into the application itself to avoid uploading photos from a photo library altogether might prove more beneficial. However, the conversion of photos from HEIC to JPEG/PNG did not delay the task by long (between 1 and 3 minutes).

Results from the user feedback form can be found below:

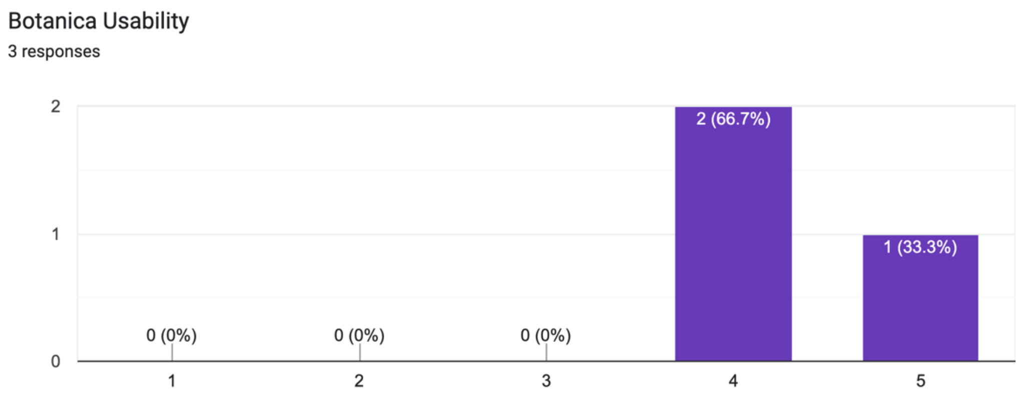


Figure 18 User Feedback on Botanica Usability

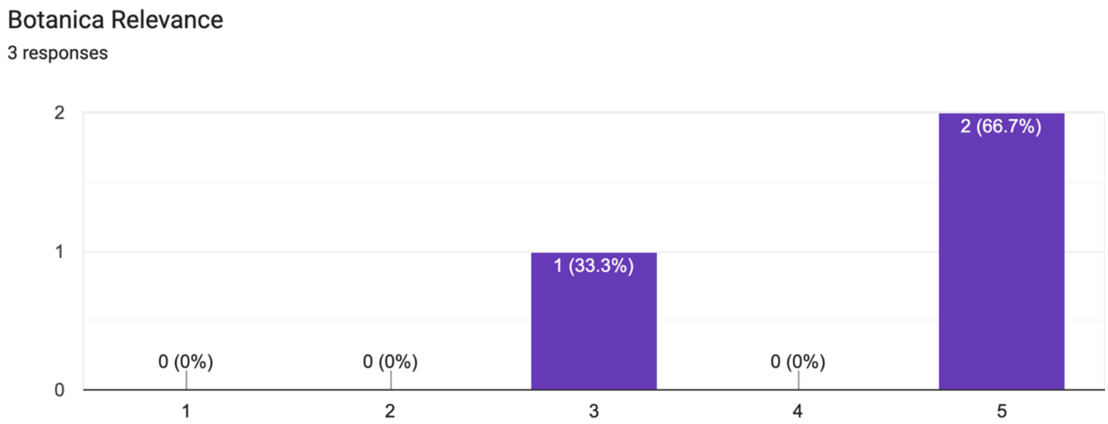


Figure 20 User Feedback on Botanica Relevance

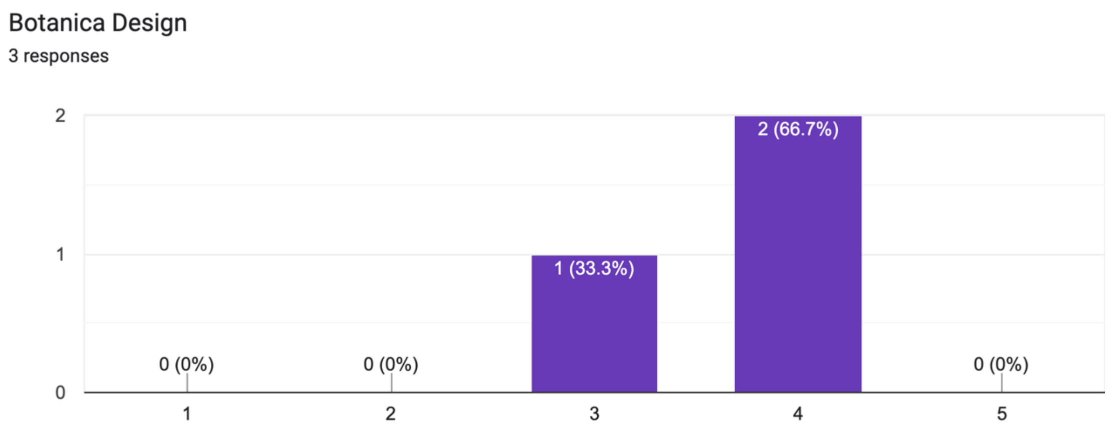


Figure 19 User Feedback on Botanica Design

In conclusion, it appears that Botanica could improve its user interface design. Other feedback suggested allowing HEIC type images, and improving the sign up process.

Chapter 7: **Results and Evaluation**

This chapter will discuss the quality of Botanica from its implementation and how its features align to research and software available in the current domain. This is followed by a verification of functional and non-functional requirements, as well as optional requirements if they were met. Finally, the legality and ethical issues of this project will be discussed.

7.1 Alignment to Research

From the research completed in chapter 2, it was seen that automation, connectivity and data analytics provide many benefits in agriculture, assuming they are implemented effectively. Effective implementation includes attributes such as minimal user input, simple user interfaces and generation of useful data. Without successfully attaining these attributes, the technology is unlikely to be adopted, and thus, is redundant.

Research has highlighted that users dealing with agricultural data tend to find collection of analysis "paralysing". As a result, the Botanica system only requires users to input 4 parameters that can easily be collected. For example, users generally know how much land they possess, soil acidity can be determined from DIY kits found at most garden centres, average temperature can be taken from a smartphone's weather app, and soil type can be determined by touch or looked up on the Internet.

As it was found that much time and money goes into manually determining what species should be planted in a particular environment, the system is able to make this judgement in a matter of seconds. This feature both increases time efficiency and eliminates the cost of human consultations. The system also has no biases or subjectivity, unlike human consultants.

After determining that users are unhappy with sharing "detailed information on their (…) operations", the Botanica system does not save the input variables of the user. Once the algorithm has been applied to the data, it cannot be found anywhere, even by the system. Storing the data would provide no additional benefits to the user, which is another reason for this sensitive information not to be stored. However, users can choose to save photographic evidence of their receipts. These receipts are individual to the registered user and cannot be accessed by any other registered user. Although receipts are not particularly sensitive data, during the upload process they are mapped only to the user that uploaded them, which can then only be accessed by being authenticated.

7.2 Verification of Requirements

By determining the number of requirements that have been met by the system is an indicator of the project's success. Therefore, the functions will be mapped to the requirements and their achievement in unit testing and expected behaviour will also be displayed.

7.2.1 Functional Requirements

View	Requirement	Passes Unit Testing
Get_input	FR3, FR4, FR5, FR6	Yes
Upload_receipt	FR7	Yes
View_receipts	FR8	Yes
Delete_receipt	FR12	Yes
Custom_login	FR2	Yes
Signup	FR1,	Yes
Log_out	FR11	Yes
Government	FR9, FR10	Yes
Non_government	FR9	Yes

Figure 21 Verification of Functional Requirements

7.2.2 Non-Function Requirements

Non-Functional Requirement	Evidence
NFR1	Botanica has been built using Django.
NFR2	The system has been tested and runs on Google Chrome, Safari and Firefox.
NFR3	The code has relevant comments throughout, with views and functions clearly described.
NFR4	Upon testing, the function took on average 15 seconds to comprehend and complete.
NFR5	Upon using the admin account, all user passwords are hashed and cannot be deduced.
NFR6	The system uses and styles buttons throughout.
NFRO1	Buttons and backgrounds only use the colours #f7f72, #f86f7c, #2f4550 and #fff
NFRO2	The sans-serif font is used in the styling of each HTML page.
NFRO3	All pages (bar log in and sign up) have the same header, design, and colour scheme
NFRO4	Personalised welcome messages are found at the top of 3/3 of the authenticated user pages.

Figure 22 Verification of non-functional requirements.

7.3 Weaknesses and Limitations

The weaknesses and limitations of Botanica's implementation and design are explored.

7.3.1 More Inclusive Algorithm

7.3.2 Increase List of Species

The data the algorithm compares the user input could be more expansive and include more species native to the UK. For example, the current implementation includes six non-government specified species that can be recommended. However, there are hundreds of flowering species that potentially benefit pollinators and could perhaps be better suited to the environmental conditions on the users land.

7.3.3 Increase Parameters Collected

The algorithm could also include and compare more parameters. For example, some algorithms look at optimal levels of nitrogen, phosphorous and potassium before recommending species [18].

7.3.4 Increase Range of Variables

The species included by the recommendation realistically have numerous optimal temperatures, soil types and soil acidities that they would flourish in. In this system, all the species have been limited to one range. For example, poppies can grow in loamy and sandy soils, but the system only recognises poppies for growing in loamy soil. However, if this logic were implemented, then there is a high chance of the same plant being recommended to all users despite their input (i.e., a species that can grow under many different conditions will be recommended the most), thus diminishing the variability of the top 3 suggestions. The current algorithm promotes the most biodiversity.

7.3.5 Saving Recommendations

A feature to save quotes was considered. This would prevent users from wasting time on inputting data for their recommendation each time. However, due to the sensitive data that the recommendation algorithm processes, this was decided against. Furthermore, the user may have different areas of land with different parameters (i.e., one field they own might have sandy soil, another loamy soil, and be different amounts of hectares).

7.3.6 Authorised Admin User

If this software were to be implemented by the British government, a high-authority administrative user would be required to be made, who can view all users and their receipts. This could be necessary for successful reimbursement. However, users could utilise the current government system in place alongside this tool to receive payments for the Countryside Stewardship.

7.3.7 Allow Users to Purchase Recommended Seeds

A disadvantage of Botanica is that it does not allow users to purchase the seeds they have been recommended. As it would be a government-authorised website, it would not be possible to apply an e-commerce feature as it goes against competitive authority regulations.

7.3.8 Handling Deletion of Receipts

Receipts are deleted with the push of one button. To make Botanica a better system, the deletion could be handled more effectively. For example, confirmation dialogue such as "are you sure?" could be included. This would definitely be beneficial given the irreversible action that is deleting a receipt.

7.3.9 Password Strength

Two of the three user's during testing took longer to sign up for Botanica than expected. Slowness was due to users misinterpreting the rules for passwords. Initially, password rules were included on the sign up page, but overpopulated the page with information, so were removed. As a compromise, a visual aid for password strength could be implemented.

7.4 Legality and Ethics

The European Union regulates information privacy through the General Data Protection Regulation (GDPR) [49]. Abiding to GDPR requires transparency, purpose limitation and storage limitation of data (amongst other principles).

Due to this, Botanica only requires a username and password, both of which are untraceable to any particular individual. The only data saved is that desired by the user, being receipts, which the user can delete from the system at any time. Finally, the information the user inputs for the algorithm to process is not stored anywhere (i.e, only stored locally for as long as the data processing lasts), as this information can be traced to a certain region in the UK, making it sensitive data.

Chapter 8: **Conclusion**

In conclusion, this project has been a success. All functional and non-functional requirements were met, all tests passed, and results from user testing ensure that Botanica can have the desired effect on user's information gap.

8.1.1 Challenges and Mistakes

Deciding what features to include and what data to process were challenging. The knowledge required for this project due to the overlap between biology and technology was larger than originally anticipated. Furthermore, switching from originally being a mobile application to web application was a difficult but necessary decision to make.

Developing an algorithm proved the most difficult and time-consuming challenge. Gathering the data for the algorithm, researching plants beneficial to pollinators, and assigning each plant species a range for each parameter and creating a point system took slightly longer than expected. This did have a subsequent effect on later iterations, mostly the iterations regarding design of the user interface.

8.1.2 Experience Gained

Confidence has been gained in developing web applications using Django and utilising the Model-View-Template (MVT) model. Using this model has built the skill of streamlining and organising code. Furthermore, the experience of completing unit tests has been very interesting, and the importance of them is now fully appreciated.

Gaining an understanding of the AgTech market has also been intriguing. Reaching the conclusion that technology has not been well implemented was very surprising, given the necessity that agriculture possesses.

8.1.3 Limitations of Botanica

Although Botanica has met all user requirements, in order to be a fully encompassing application, it should realistically offer users an opportunity to purchase seeds through the system or include redirects to where this is possible. However, given the nature of this being used for a government scheme, it seemed unnecessary to include this into the scope, as governments do not possess their own seeds, it would be unfair to select a certain branch of seed sellers over another.

8.1.4 Future Work

If given more time, the algorithmic models used in research today would have been studied, possibly including machine learning. However, the existence of these models was only uncovered after the botanica suggestion algorithm had already been implemented.

Finally, it would have been preferable to have a more interesting user interface (i.e., perhaps not static). With this in mind, it would have been better to explore more appealing design options.

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