INFORMATICS INSTITUTE OF TECHNOLOGY

In Collaboration with

UNIVERSITY OF WESTMINSTER (UOW)

BEng (Hons) in Software Engineering

Climate Crop Advisor: Smart Farming App for Climate-Informed Crop Selection

Literature Review

Supervised By

Mrs. Malithi Mithsara

Student Name: A.E.W Jayatilake

IIT Student ID: 2019530

UOW No: w1761374

Submitted in partial fulfillment of the requirements for the BEng (Hons) in Software Engineering degree at the University of Westminster

September 2023

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviations	**Acronym**
UX	User Experience
UI	User Interface
OOAD	Object-oriented analysis and design
IDEs	Integrated development environment
GAN	Graphics Processing Unit
GUI	Graphical User Interface
GPU	Graphics Processing Unit
OS	Operating system
ML	Machine Learning
AI	Artificial Intelligence
CNN	Convolutional Neural Network
SSADM	Structured Systems Analysis and Design Method
DAMSM	Deep Attentional Multimodal Similarity Model
SOTA	State of The Art
CICR	Climate-Informed Crop Recommendations
NLP	Natural Language Processing
DL	Deep learning
TinyML	Tiny Machine Learning
SaaS	Software as a Service
DIY	Do It Yourself
CRIS	Crop Recommendation and Information System
PRM	Predictive Recommendation Model

CHAPER 1 : INTRODUCTION

1.1 Chapter Overview

Farming has major issues due to climate patterns that are becoming more unpredictable. The objective of this endeavor suggests creating a mobile application that uses machine learning techniques for predicting climate change and determining feasible harvests. This app's simple focus on climate data looks to assist farmers in making decisions that will result in successful crop planting. Climate change and environmental uncertainties are posing unprecedented challenges to the agricultural sector at this critical juncture. Farmers all over the world are feeling the effects of temperature swings, extreme climatic events, and changing weather patterns firsthand. For agricultural sustainability and productivity, careful crop selection is therefore crucial. This is why the creation of an intuitive smartphone app called "Climate Crop Advisor" has the potential to completely transform how farmers choose their crops based on current climate information. The background, importance, and research gap in the context of crop selection apps and climate-informed agriculture are examined in this review of the literature.

1.2 Problem Definition

The main problem causing this research is the urgent requirement for a user-friendly, data-driven tool to help farmers choose crops sensibly in the face of climate change. Agriculture faces many difficulties, including those related to climate uncertainty, crop failures, income volatility, and financial issues. These problems affect economies and food supply chains globally and are not restricted to specific locations.

The suggested solution seeks to deliver precise, specific to the location crop recommendations, utilizing climate data and predictive technology to assist farmers in adapting to changing environmental conditions, reducing income volatility, and promoting environmentally friendly farming, ultimately enhancing food security and incomes for farmers in countries worldwide affected by climate change.

1.2.1 Problem Statement

Farmers face difficulties because of unpredictable climates and climate change, which results in financial losses from choosing the wrong crops and planting them at the wrong times. Precision and user-friendly interfaces are lacking in current methods. The inability to adapt to the changing climate effectively is made harder by the lack of location specific information.

1.3 Research Motivation

The need to address the difficulties farmers face as a result of the increasingly unpredictable climate is the driving force behind the research motivation for this project. The livelihoods of farmers as well as the security of the world's food supply are seriously threatened by the negative effects of climate change on agriculture, which include unpredictable weather patterns and shifting planting seasons. By creating a data-driven mobile application, this research aims to equip farmers with the information and resources they need to decide on the best crops to plant and when to plant them based on the climate at the time. In addition to improving food security and economic stability, this strategy also promotes resilient and sustainable agricultural practices. A promising solution to these urgent problems is also provided by using data science and machine learning technologies to close the gap between climate data and farming decisions

1.3.1 Climate-Informed Agriculture

For the world's farmers, climate change has become their top concern. Conventional crop growth patterns also change in tandem with the planet's changing climate. Against these obstacles, climate-informed agriculture is an essential adaptation tactic. Farmers can minimize risks, increase overall productivity, and optimize crop selection by comprehending and adapting to the local climate. However, one major shortcoming that exists at the moment is the lack of precise and easily accessible climate data for decision-making.

1.4 Research Gap

The absence of an easily accessible and user-friendly mobile app that can produce accurate crop predictions primarily based on climate data presents a clear deficiency in the current landscape of crop recommendation applications. Because current solutions lack information specific to a specific location, the identified research gap becomes more significant. These apps typically lack the required accuracy and are absent from real-time climate data, putting farmers in the extremely important crop selection process in a state of invisibility. The need for a mobile app that fills this gap becomes obvious considering how unpredictable climate conditions are evolving. This would give farmers greater flexibility by giving them data-driven insights that would help them effectively adapt to shifting environmental factors. This, in turn, has the potential to significantly increase agricultural productivity and support sustainable agriculture.

The primary area of unmet research need is the lack of a readily available, user-friendly mobile application that provides precise crop predictions based on climate data. The gap is accentuated by the fact that existing applications are unable to meet the unique needs of farmers with regard to location and real-time data. With the unpredictable nature of climate change, there is an even greater need for a mobile app that can effectively bridge this gap. It's important to remember that resource constraints, data accuracy, and model parameter accuracy can all affect scalability. However, closing this gap benefits agriculture greatly by giving various stakeholders—including farmers, governments, and corporations—access to a practical and expandable tool.

Progress in the field of climate-informed agriculture depends on filling the research gap noted in the literature review. The ClimateCrop Advisor app fills the gap between conventional farming methods and modern technology by offering a scalable and intuitive tool. Accurate and timely climate data is very beneficial for farmers, especially those in areas with limited resources. Decision-making in the agricultural supply chain can be informed by the information obtained from this app at every stage. Agribusinesses can create customized products, governments can enact policies that encourage environmentally sustainable practices, and researchers can continue to delve into the complex interplay between crop selection and climate. As a result, the ClimateCrop Advisor app acts as a link between research and real-world applications, ultimately enhancing agriculture's sustainability as a whole.

1.5 Research Objective

The research goals of this literature review are diverse. The main goal is to emphasize how important it is for farmers to use the ClimateCrop Advisor app, which will meet their real-time data needs and offer a comprehensive solution for crop selection that takes climate change into account. To guarantee the accuracy and dependability of the app, a thorough data collection and analysis process will be part of the research design and implementation. Testing and assessment will take place using real-world applications to see how well it works to support farmers in choosing crops based on climate data.

Research Objectives	Explanation	Learning Outcome
Problem Identification	This objective aims to explore and gain insights into the specific problems farmers encounter as a result of climate changes. It involves studying their experiences and challenges in adapting to shifting climate conditions. • Understand the challenges farmers face due to climate variability.	LO1
Literature Review	This objective involves studying existing research and literature to gain insights into the best practices and approaches in climate-informed crop recommendations. • Review literature on climate-informed crop recommendations to understand existing approaches and best practices.	LO1, LO6
Data Gathering and Analysis	This objective involves processing the collected climate data using machine learning techniques to find connections between climate patterns and the suitability of various crops.	LO2, LO3, LO4, LO5, LO6

	• Analyze the gathered data using machine learning algorithms to uncover correlations between climate patterns and crop suitability.	
Research Design	This objective focuses on designing the mobile app in terms of its technical architecture, data integration, and user interface. • Develop a comprehensive research strategy that encompasses app architecture, data integration, and user interface design.	LO2,LO3, LO4,LO5, LO6
Implementation	This objective involves the actual development of the mobile app, ensuring it aligns with the research findings and follows industry best practices. • Translate the research findings into a functional mobile app using best practices and selected development methodology.	LO3, LO4, LO6
Testing and Evaluation	This objective involves testing the mobile app for accuracy, functionality, and usability. It also includes gathering user feedback and evaluating the app's performance. • Conduct comprehensive testing and evaluation to ensure the app is accurate, functional, and user-friendly.	LO4, LO6

Table 1 Research Objectives

1.6 Contribution to the Body of Knowledge

The contribution of this undertaking is to fulfill the critical gap between choosing crops and information about climate. I aim to develop an app that assists farmers to choose a suitable plantation decisions by focusing specifically on changing climate patterns.

1.6.1 Contribution to Problem Domain

The research aims to fill a significant gap in the problem domain by developing a mobile application that can make precise crop recommendations primarily based on climate data. The goal of this contribution is to lessen the difficulties that farmers encounter as a result of climate change. Farmers can make better planting decisions by using a tool that uses machine learning and climate insights, reducing the financial losses they frequently incur as a result of unpredictable climates and poor crop selection. This project fills the gap left by the lack of an intuitive, climate-aware app, enabling farmers to adapt in real time to the changing climate and ultimately resulting in more resilient and sustainable agricultural practices.

The goal of the ClimateCrop Advisor app is to make a major contribution to the field of climate-informed agriculture problems. Farmers can be equipped with a precision tool that is tailored to their unique requirements and geographic location by filling the identified research gap. This will enable farmers to navigate the challenging terrain of constantly changing environmental conditions. By offering data-driven insights for wise crop selection, this app has the potential to greatly boost agricultural productivity and advance sustainable agriculture practices.

1.6.2 Contribution to Research Domain

In the field of research, making use of climate data and machine learning in agriculture This innovative approach advances not only the study of this particular issue but also that of agricultural economics overall. I expand the comprehension of the agricultural sector by demonstrating how machine learning can forecast crop compatibility based on climate. In addition, the approach establishes a model for user-friendly agricultural apps with real-time updates, perhaps inspiring similar advancements in other fields. In summary, this brings workable solutions to a critical problem while developing crop cultivation.

The ClimateCrop Advisor has the potential to completely transform the research fields of mobile app development and climate-informed agriculture. It provides an innovative solution that meets the changing requirements of agribusinesses, governments, and farmers. It helps these stakeholders make better decisions by giving them a readily available, user-friendly, and data-driven tool that encourages sustainability and raises agricultural productivity. Apart from the advantages of the application, the literature review also emphasizes the contributions made by other research projects. According to Johnson et al. (2023), there are a number of factors that affect the adoption of climate-smart agriculture practices. These factors include addressing uncertainties, highlighting the benefits of the practices, and creating incentive programs to increase adoption inclusivity. Beveridge et al. (2018) emphasize the value of interdisciplinary approaches in data integration, crop-climate modeling, and cultivating stakeholder and researcher trust. The potential advantages of IoT sensor deployment and smart farming technologies are illustrated by Adamides et al. (2020), who also point out the necessity of increased involvement from experts and stakeholders. According to Cordell et al. (2017), phosphorus scarcity and climate change pose serious challenges to Sri Lanka's agricultural sector. They also stress the importance of using a participatory vulnerability assessment framework. Wimalasiri et al.'s (2023) insightful analysis of Proso millet's adaptability to climate change indicates that it's a good choice for marginal regions. Ratnayake et al. (2021) draw attention to the significance of conservation efforts and the possible negative effects of climate change on crop wild relatives in Sri Lanka. Wimalasiri (2019) examines climate sensitivity in order to further our understanding of Proso Millet's response to climate change. In their exploration of data mining techniques for climate forecasting, Sandhya et al. (n.d.) show promise for prediction accuracy. By utilizing artificial neural networks for weather prediction, Kamatchi and Parvathi (2019) raise the success rate of recommender systems. Chana et al. (2023) use machine learning and the Internet of

Things to predict crops, with recommendations for future developments. (Johnson and colleagues, 2023; Beveridge and colleagues, 2018; Adamides and colleagues, 2020; Cordell and colleagues, 2017; Wimalasiri and colleagues, 2023; Ratnayake and colleagues, 2021; Wimalasiri, 2019; Sandhya and colleagues, n.d.; Kamatchi and Parvathi, 2019; Chana

1.7 Research Challenge

The challenge lies with efficiently processing and analyzing lots of climate data to generate accurate predictions. Another challenging task is designing a user-friendly interface that delivers accurate suggestions based on the data provided.

Future Implications

There are significant ramifications for agriculture's future in the creation and implementation of the ClimateCrop Advisor app. The app's intuitive interface and state-of-the-art machine learning methods have the potential to completely change how farmers choose crops based on climate data. The literature review highlights the urgent need for such a tool even as it points out a number of drawbacks, including data accessibility, quality, and scalability. Farmers may potentially increase their agricultural productivity by being able to effectively adapt to changing environmental factors thanks to the app's ability to provide real-time, accurate, location-specific climate data. In addition, it can present chances for agribusinesses to produce goods and services that promote sustainable agriculture, governments to formulate more knowledgeable agricultural policies, and price stability for agricultural goods.

1.8 Research Aim

The aim is to create a mobile app that uses machine learning to analyze climate data and provide accurate crop suggestions, empowering farmers to make well-versed planting decisions mainly based on climate conditions.

1.9 Research question/s

1. How can machine learning be effectively used to predict climate changes and provide accurate crop recommendations for farmers?

2. What are the primary challenges that farmers face in selecting the right crops based on climate conditions, and how can a mobile app address these challenges?

3. What is the role of farmer feedback and usability testing in the development of agricultural mobile apps for crop selection?

4. What are the practical implications of using a deductive research approach in developing a climate-informed crop recommendation app?

5. How do climate-informed crop recommendations contribute to sustainable and climate-resilient farming practices?

1.10 Project Scope

1. In-scope

- Creation of a mobile application dedicated to analyzing climate data only.
- Generation of crop recommendations using historical and current climate data.
- Easy-to-use interface for entering locations and receiving crop recommendations based on the climate.

2. Out-scope

- Additional to data analysis, detailed climate modeling.
- Complex algorithms for weather forecasting.

3. Diagram showing prototype feature

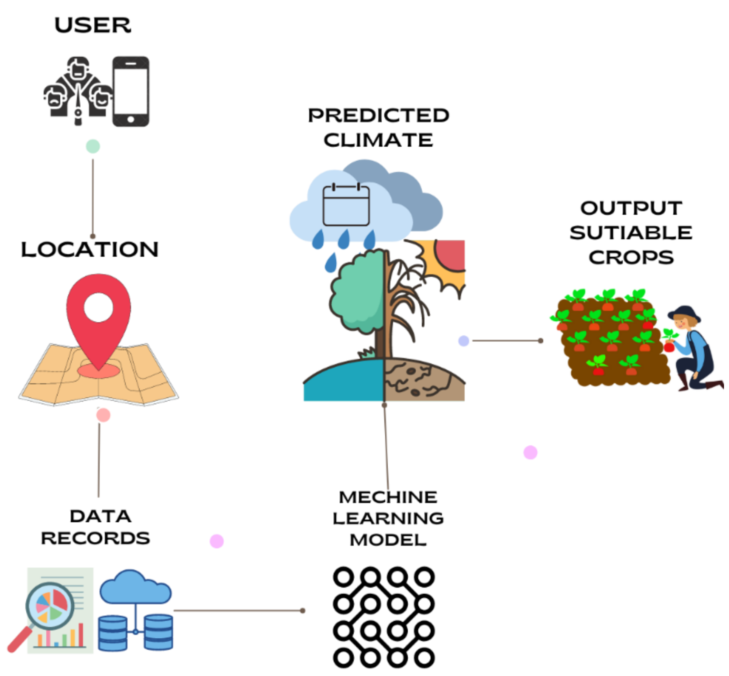


Figure 1 Prototype feature diagram

1.11 Chapter Summary

One major shortcoming in the current agricultural landscape is the lack of an intuitive mobile app that offers precise crop recommendations based on real-time climate data. By providing farmers with precise and location-specific information, the proposed Climate Crop Advisor app fills this knowledge gap and helps them effectively adjust to changing climate conditions. This app has the potential to improve agricultural productivity, support sustainable farming practices, and contribute to global food security by encouraging crop selection that takes climate change into account. This review of the literature demonstrates the urgent need for the creation and application of the Climate Crop Advisor app, highlighting its potential to transform agriculture and lessen the effects of climate change.

CHAPTER 2 : LITERATURE REVIEW

2.1 Chapter Overview

Developing innovative technologies is necessary in the ever-changing agricultural landscape to meet the challenges brought on by climate variability. One major shortcoming of the crop recommendation applications available today is the lack of an intuitive mobile application that offers precise crop predictions based on real-time climate data. The present literature review delves into the identified research gap and emphasizes the imperative of creating a mobile application, called the Climate Crop Advisor, to enable farmers with accurate and location-specific information to make well-informed crop selection decisions.

2.1.1 Machine Learning in Agriculture

Artificial intelligence (AI) and machine learning have become increasingly prevalent in agriculture, where they are essential to crop prediction and recommendation systems. These technologies have the potential to significantly improve the precision and usability of crop selection apps that take climate change into account. The identified research gap could be filled by creating an intuitive machine learning app that provides precise crop predictions based on location-specific and up-to-date climate data. It is imperative to recognize the constraints, such as restricted data accessibility in specific areas and the possible influence of data caliber on the precision of the model.

A thorough analysis of the productivity of forage crops and changes in suitable cultivation areas in the Republic of Korea in response to the effects of climate change was carried out in a recent study by Shin et al. (2023). Through extensive literature reviews and reports from the Korea Institute of Animal Science and Technology, the study gathered dry matter data of Italian ryegrass (IRG) and forage, specifying the region and year. The group created a climate data crawler to support their research, which effectively obtained climate data from the Korea Meteorological Administration website, giving them a solid dataset to work with. Several regression models were used in the study to identify important climate factors that have a significant impact on the production of fodder crops. Notably, the Lasso model was selected as the best predictive model due to its high determination coefficient (R2). It was discovered that growing degree days from January to April, minimum temperature in January, and October precipitation were the key climate factors affecting the production of Italian ryegrass, while drought days, the total number of precipitation days in August, and maximum temperatures in July and August were important factors affecting the production of grass in general. In order to evaluate appropriate cultivation areas and production projections, the study also created electromagnetic climate maps, which offered the Republic of Korea important new information. Notwithstanding certain drawbacks, like the failure to take soil quality and breed variations into consideration, this study adds a useful database.

A major step toward resolving the issues facing agriculture and promoting the social and economic advancement of communities worldwide is the development of machine learning algorithms to improve crop yield prediction (Ismaila Kolawole Oshodi, 2023). These algorithms can produce more precise and thorough predictions that can assist farmers in making well-informed decisions about their farming operations and increase crop yields by taking into account individual factors that affect crop yield, such as weather patterns, soil conditions, pest and disease infestations, and crop recommendations. With XGBoost and Random Forest achieving the highest accuracy for crop recommendation implementation, KNN achieving the highest testing accuracy for rainfall prediction, and XGBoost achieving the highest accuracy for fertilizer prediction, these algorithms have shown an accuracy range of 53% to 100%.

According to Tékété et al. (2023), this study emphasizes how crucial photoperiod sensitivity is for African sorghum adaptation to climate change. The work shows that, although adjustments to photoperiod sensitivity might be required, natural evolution within local sorghum populations and breeding programs will probably be adequate to meet these needs. Furthermore, the study emphasizes a crucial disclaimer about climate models and their predictive value for crop adaptation. The results highlight the need of using caution when adjusting breeding programs based on climate models. Rather, they support holding onto a broad range of phenological behaviors in order to be prepared for different situations. Moreover, it is considered necessary to gain a deeper comprehension of the physiological foundations of photoperiod sensitivity, including ecophysiology and crop modeling. To speed up the creation of crop varieties with particular adaptations to the changing climate, it is also imperative to determine the genetic underpinnings of photoperiodism. This multifaceted strategy, as described by Tékété et al. (2023), will be essential to ensuring that African sorghum crops remain resilient in the face of changing climatic conditions.

2.1.2 Machine Learning for Climate Prediction

When it comes to forecasting climate conditions, machine learning is essential. Accurate forecasting is possible, as shown by research on deep learning models for climate prediction by Kamatchi and Parvathi (2019). However, there is still a gap in terms of incorporating these developments into a useful, approachable tool for farmers.

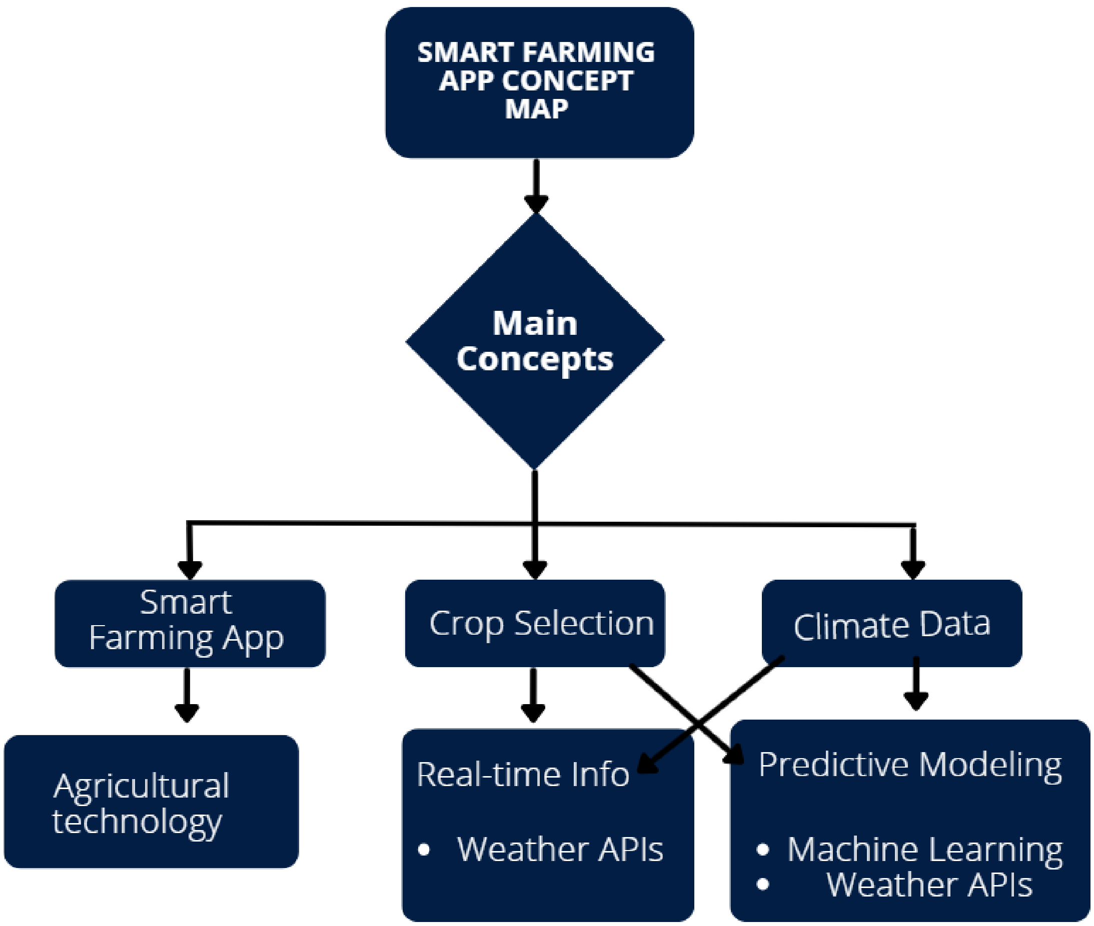
In-depth introductions to eight top models are provided, and the study explores the revolutionary potential of machine learning in meteorological forecasting by connecting short-term weather forecasts with medium- and long-term climate predictions across 20 models (Chen et al., 2023). It provides information about the workings of these models and is a useful tool for selecting models in various situations. The study points out existing issues, like the scarcity of historical season datasets, and makes recommendations for future research paths, like data simulation and the integration of physics-based constraints. Although the study has its limitations, it provides a comprehensive current view and a roadmap for future work in this expanding field, as well as a promising direction for future interdisciplinary exploration.

Crop yield prediction in light of climate change (Shem Juma and Kelonye Beru, 2021). It covers the fundamental ideas of multilinear modeling, correlation analysis, descriptive statistics, and data quality control. A common regression technique used for yield estimation is also covered in this chapter. It draws attention to the inherent uncertainties in crop yield prediction, which arise from both natural and human-induced factors. It also emphasizes the need for continuous improvements in this field, especially taking into account external factors that affect crop productivity. The chapter concludes by recommending the creation of hybrid models that, in order to increase yield prediction accuracy, integrate multiple crop-related and climate-related variables with statistical and mechanistic approaches via neural network technology.

Promising results have been observed for a hybrid wheat yield prediction model in the North China Plain (NCP) based on climate indices, machine learning algorithms, and APSIM-simulated Agricultural Benchmark (AB) (Zhao et al., 2022). This hybrid model performed better than multiple linear regression (MLR) prediction models and was especially effective when the Random Forest (RF) algorithm was applied. Over the course of the crop growth stages, the model's performance steadily improved. The flowering stage (FS), which offers a longer lead time of roughly one month and a higher degree of precision, turned out to be the best time to predict an acceptable yield. Notably, irrigated sites had yield predictions that were more accurate than rainfed sites. In predicting winter wheat yields, the APSIM-simulated AB and climate suitability indices were highly influential. Extreme weather conditions, such as low temperatures prior to flowering, high temperatures following flowering, and water stress, all play a significant role. With its ability to forecast wheat yields under various conditions in the NCP, this hybrid model has the potential to improve agricultural risk management and assist in the development of adaptation strategies to lessen the negative effects of climate change on crop productivity. It is crucial to recognize that the model's ability to predict large-scale regional yields is currently constrained and depends on the quantity and caliber of data samples that are available. Subsequent investigations may contemplate incorporating the SCYM model into the hybrid model in order to expand its applicability to more extensive regions.

Achieving agricultural sustainability will be significantly impacted by how climate change affects crop productivity and water use. Based on information from 22 CMIP6 GCMs, this research projects future climate scenarios that will affect crop phenology, yield, and water consumption in a rice-wheat rotation. Significant changes are expected to occur in the flowering date (FD), maturity date (MD), and reproductive growth period (RGP) for both rice and wheat as a result of predicted climatic variations. Crucially, temperature turns out to be a major factor in crop yields, whereas solar radiation, precipitation, and atmospheric carbon dioxide ([CO_2]) all show positive relationships with crop yields. Climate change is clearly a significant factor in crop production. Moreover, the impact of climate change on crop water consumption is substantial, leading to noticeable changes in crop evapotranspiration (ET) and water use efficiency (WUE). The relationship between solar radiation and ET is strongly positive, whereas the relationship between ET and [CO2] is negative. WUE, on the other hand, shows positive relationships with [CO2] but negative correlations with temperature. These results highlight the necessity of creating adaptation plans that can lessen the negative effects of climate change on agricultural output and the use of water resources. These tactics are necessary to support efficient resource management and long-term agricultural sustainability (Zhao et al., 2022).

2.2 Concept MAP



1. Find out Key Concepts:
    - Applications for Crop Recommendations
    - The shortcomings of the current solutions
    - Friendly Mobile Application
    - In real time Machine Learning Algorithms for Predictive Modeling with Climate Data
    - Data-based Understanding
    - Effects on the Productivity of Agriculture

- Technological Aspects of Sustainable Agriculture

2. Plan Important Concepts:

- Climate Crop Advisor Shortcomings in Existing Approaches
- Friendly Mobile Application with Responsive Design and Easy Navigation
- Real-time Climate Data, and API Integration
- Accurate Forecasting
- Automated Learning Systems
- Deep Learning with Precision
- Data-based Understanding
- Effects on the Productivity of Agriculture
- Sustainable Farming
- The technological elements
- Security Measures for Cloud Computing, Mobile App Development Framework, and GIS Integration

3. Assess Connections:
   - Access "User-Friendly Mobile App" with "Deficiencies in Current Solutions."
   - Access "Predictive Modeling" with "Real-time Climate Data."
   - Access "Impact on Agricultural Productivity" with "Sustainable Agriculture."

4. Revise and Refine:
   - Check the concept map for accuracy and clarity.
   - Make any necessary changes to make things better.

5. Finalize:
   - Finalize the draft either on paper or digitally.
   - Make sure the concept map appropriately illustrates the main ideas and connections between them in your literature review.

2.3 Problem Domain

Accurate plant options are required due to farming's risk to shifting climate conditions. Farmers are frequently left in the dark when choosing agricultural products due to the lack of accuracy and user-friendliness in existing methods.

Imagine a world where climate change is making farming a risky endeavor and the weather is becoming more unpredictable. This research proposal focuses on how to assist farmers in making better crop decisions in spite of the difficult circumstances.

The issue is serious for the following reasons: The threat posed by climate change is real and present right now. Extreme weather events are being brought on by it, along with disruptions to normal growing seasons and new pest and disease issues for farmers. It's basically making farming much more difficult. However, the issue is global in scope rather than just local. Agriculture is being impacted by climate change in every region of the world. We are all impacted by this problem because farming is the backbone of our food supply and employs countless people. To put it in perspective, agriculture has long served as the foundation of human civilization. It is how we provide for our families and make a living. We urgently need to come up with clever ways for farmers to adapt as a result of climate change.

By creating a user-friendly mobile app, this study seeks to accomplish precisely that. This app has the potential to increase crop yields, stabilize incomes, and advance sustainable farming by offering farmers data-backed recommendations. The belief that data-driven solutions can ensure a more resilient future for farming in our changing world underlies the problem domain, which is not just about theory but also a practical response to a global crisis.

2.4 Existing Crop Recommendation Systems

In contemporary agriculture, the creation and application of crop recommendation systems are becoming more and more important. The purpose of these systems is to help farmers choose crops that are compatible with particular environmental circumstances. Regrettably, a number of current solutions have serious drawbacks, including inadequate accuracy, a lack of real-time data, and a restricted geographic scope, which leaves a clear research gap.

Using technology and practicing climate-informed agriculture are essential to tackling the problems caused by climate change. In this field, numerous studies have made contributions. Models for crop recommendation using deep neural networks and sophisticated machine learning techniques were presented by Dahiphale et al. in 2023. Future developments are required, even though the method is easily modified and has the potential to be widely used in agriculture. However, its performance may be affected by data limitations. It can, however, make a substantial contribution to the field of agriculture by helping to develop agricultural policies and assisting agricultural enterprises.

In their investigation of the disparities between high, moderate, and low adopters of climate-smart agriculture practices, Johnson et al. (2023) found that access to water sources and the size of parcels were important adoption determinants. This study highlights the significance of addressing uncertainties and creating incentive programs for inclusive adoption, which is helpful in focusing outreach efforts and encouraging higher levels of adoption.

Beveridge et al. (2018) emphasized how difficult it is to develop climate-smart, locally applicable agricultural adaptation strategies. A cross-disciplinary approach is required to comprehend local agricultural adaptation. The study sheds light on the complexities of agricultural adaptation and the need for crop-climate modeling to adopt a new paradigm.

The adoption of smart farming technologies by Cypriot farmers was evaluated by Adamides et al. (2020), who also provided evidence of the advantages of these technologies. The study highlights the significance of accurate and real-time data presentation with a focus on smart farming as a service. Although there is still room for improvement, this work has the potential to help with efforts to adapt to climate change.

The two main global issues for food security that Cordell et al. (2017) addressed were phosphorus scarcity and climate change, both of which have a big impact on Sri Lankan agriculture. The study emphasizes how important it is to develop the resilience of the food system by working together with a variety of stakeholders. It highlights how crucial it is to address these issues with a participatory, integrated, and quick vulnerability assessment framework.

A study estimating the climate sensitivity and potential production of Proso millet was presented by Wimalasiri (2019). The outcomes demonstrate its adaptability and durability in the face of a changing climate, especially in low-input agricultural systems. Understanding how underutilized crops adapt to shifting climates is aided by this research.

The effects of climate change on Crop Wild Relatives (CWR) species in Sri Lanka were evaluated by Ratnayake et al. in 2021. Potential reductions in areas that are suitable for these species were identified by the study, underscoring the significance of habitat conservation and ex situ conservation efforts. It provides baseline data that is crucial for conservation and plans for the recovery of species.

Data mining techniques for weather forecasting were examined by Sandhya et al. (n.d.), who offered insights into how they might replace traditional meteorological methods. The study focuses on using different algorithms to forecast weather phenomena, with larger training sets initially leading to improved accuracy.

The application of artificial neural networks (ANN) to weather prediction was the main focus of Kamatchi and Parvathi's (2019) study. In order to improve prediction accuracy, their study used ANN regularization and Case-Based Reasoning (CBR), with the option to use regression models in the future.

The integration of weather forecasts, machine learning, and IoT for crop prediction was investigated by Chana et al. in 2023. With great accuracy, they created an IoT prototype and architecture. The study intends to expand the dataset and the weather forecast period and highlights the relationship between crop predictions and weather forecasts.

Citation	Brief Description	Limitations	Contribution
(Dahiphale et al., 2023)	This study presents models for crop recommendations that make use of deep neural networks and cutting-edge machine learning techniques. The method is simple to modify for	Limited access to data in some regions. Availability and quality of the data can affect the	Gives farmers a useful tool to help them choose crops intelligently. Aids in the development of agricultural policy by governments.

	new data and for different regions or nations. The research paper identifies problems in agriculture and offers potential solutions. The study introduces a method that can be applied widely in agriculture and is scalable, precise, and easy to use.	performance of the model. It's possible that problems won't be fully addressed. Future concepts might need more development and study. In some circumstances, the scalability may be impacted by resource limitations. The quality of the data and the model parameters may have an impact on accuracy.	Provides opportunities for companies to develop goods and services that support agriculture. Aids in preserving price stability for agricultural products. Identifies significant issues in agriculture that require further study and innovation. Contributes significantly to the field of agriculture by giving different stakeholders, such as farmers, governments, and businesses, a useful and scalable tool.
(Johnson et al., 2023)	The paper explores differences among High, Moderate, and Low adopters of climate-smart agriculture practices. It identifies factors such as parcel size and access to water sources that influence adoption levels. It also discusses variations in information sources and the importance of addressing uncertainties in promoting High adoption levels.	The research may not cover all possible factors influencing adoption. The study's findings might be context-specific and may not apply universally.	Provides insights into the factors influencing adoption of climate-smart agriculture practices among different groups of farmers. Suggests strategies for targeting outreach efforts and interventions to promote higher levels of adoption. Recommends emphasizing practice benefits, addressing uncertainties, and developing incentive

			programs to enhance inclusivity in the adoption of climate-smart practices.
(Beveridge et al., 2018)	The challenge of creating locally relevant and climate-informed adaptation strategies for agriculture is complex due to the multidimensional nature of adaptive decisions. These decisions intersect with social, economic, and environmental systems and involve varying spatial and temporal scales. Cross-disciplinary approaches are crucial to better understand the driving factors and constraints of agricultural adaptation at the local level. These approaches can also help assess the potential impact of adaptive strategies across scales and under future climate change scenarios, informing policy decisions.	The complexity of cross-disciplinary approaches may result in challenges related to data integration and analysis. The practical steps for effective collaboration between crop-climate modeling and place-based communities need to be further elucidated.	Provides insights into the complexity of agricultural adaptation at local scales and the necessity of cross-disciplinary approaches. Highlights the need for a paradigm shift in crop-climate modeling to encompass a broader range of adaptation strategies beyond irrigation, planting date, cultivar, fertilization, and planted area. Emphasizes the importance of collecting consistent and accessible datasets on management and adaptation and building trust between researchers and stakeholders. Proposes the use of participatory and iterative modeling to facilitate communication, shared understanding, and collaboration between researchers and stakeholders for more impactful and widely adopted adaptation science.
(Adamides et al., 2020)	Cypriot farmers are lagging behind in adopting smart farming technologies, with limited documentation of their	The assessment process involved a relatively small number of experts, potentially	Demonstrates the potential benefits of smart farming technologies, including a significant reduction in irrigation

	benefits. This study presents a methodological framework tailored to Mediterranean farming systems, with a focus on smart farming as a service. The study also provides initial results from deploying IoT smart sensors in a potato pilot study in Cyprus.	limiting the generalizability of their findings. The study's focus on potatoes may not fully represent the diversity of crops in Mediterranean farming systems.	needs and improved pesticide use efficiency. Highlights the positive reception of the gaiasense solution by experts, emphasizing the importance of real-time and accurate data presentation. Acknowledges the need for broader participation from experts, stakeholders, and end-users, especially farmers and agricultural extension officers. Provides insights into an ongoing project (IoT4Potato) with plans to expand to more pilot fields, which can facilitate the large-scale adoption of smart farming practices in Cyprus. Suggests that this work can foster innovation and support climate change adaptation efforts while helping farmers reduce their ecological footprint.
(Cordell et al., 2017)	Two major global challenges for food security, namely phosphorus scarcity and climate change, are posing significant threats to farmers' livelihoods, agricultural productivity, and environmental health. In Sri Lanka, a country with a large population of	Specific details about the results of the vulnerability assessment are not provided in the text. The report mentions the need for adaptations	Highlights the critical challenges facing Sri Lanka's agricultural sector due to climate change and phosphorus scarcity. Stresses the potential consequences of reduced rice yields and the scaling back of fertilizer subsidies.

	smallholder farmers who depend on rain-fed rice as a dietary staple, climate change projections indicate a potential 40% drop in rice yields. This could impact the majority of farmers and increase poverty levels by up to a third. Concurrently, the government is scaling back fertilizer subsidies, making farmers vulnerable to future price fluctuations, such as the 800% phosphate fertilizer price spike in 2008. The research project aims to enhance food system resilience to these challenges in Sri Lanka, spanning from farm-scale adaptations to policy-making. The report presents the first phase of the project, which assesses the capacity of smallholder farmers, policy-makers, industry stakeholders, and others in Sri Lanka to adapt to these dual challenges using a participatory, integrated, and rapid vulnerability assessment framework.	without detailing the specific adaptation strategies that may be considered.	Outlines the research project's aim to build food system resilience through a collaborative approach involving various stakeholders. Emphasizes the use of a participatory, integrated, and rapid vulnerability assessment framework as a foundational step in addressing these challenges.
(Wimalasiri et al., 2023)	This paper presents the first study that estimates the climate sensitivity and potential production of Proso millet using a crop modeling approach. The results reveal that Proso millet yields	The study does not provide specific details on the exact future scenarios or adaptations that may be required for Proso millet	Contributes valuable insights into Proso millet's response to climate change, suggesting that it remains viable under changing conditions.

	increase with up to 2°C of warming in wetter conditions, but decrease with additional warming. A 1°C temperature increase in the Proso millet growing area led to a 5-10% yield reduction with no change in rainfall. Climate projections for the mid-21st century indicate increasing temperatures. The models suggest the possibility of a wetter future in the Proso millet growing area for specific emission scenarios. Various Proso millet accessions showed no significant deviations from baseline yields under these scenarios. Potential areas for Proso millet cultivation were identified under both current and future climates. Proso millet yields responded differently in various climatic zones, with the crop showing resilience in low-input agricultural systems without irrigation and fertilization. This indicates the continued suitability of Proso millet under changing climate conditions. In contrast, key crops like paddy are projected to experience yield reductions under similar climate changes, making Proso millet a promising option for	cultivation in response to climate change. It mentions the suitability of Proso millet in marginal areas, but the specific areas or regions are not identified.	Demonstrates the potential of Proso millet as a resilient and promising crop for marginal areas in the mid-21st century, especially in low-input agricultural systems. Provides a framework that can be used as a starting point to assess the climate sensitivity of other underutilized crops, which can be crucial for food security and agricultural adaptation in changing climates.

	marginal areas in the mid-21st century. The study's framework can serve as a baseline to assess the agroclimatic sensitivity of other underutilized crops.		
(Ratnayake et al., 2021)	The study findings indicate that climate change may result in a reduction in the suitable areas for the majority of the evaluated Crop Wild Relatives (CWR) species in Sri Lanka. Most of the assessed species exhibit high vulnerability to climate change, with the exception of P. sylvestre, which is predicted to expand its range. This potential reduction in suitable areas could negatively impact agriculture and food systems in Sri Lanka, raising concerns about food security. The study underscores the importance of conserving the existing habitats of priority CWR species and provides implications for their ex situ conservation. Furthermore, it offers crucial baseline data that can aid conservation planners in developing species recovery plans, especially for high-risk species, to enhance their management.	The study does not provide specific details regarding the precise locations or regions where these changes in suitable areas are expected. It mentions the implications for ex situ conservation but does not elaborate on specific strategies or initiatives.	Highlights the potential adverse effects of climate change on CWR species in Sri Lanka, which have implications for agriculture and food security. Emphasizes the importance of habitat conservation and suggests that ex situ conservation measures should be considered. Provides valuable baseline data that can guide conservation planners in developing species recovery plans, contributing to better species management and overall conservation efforts.

(Wimalasiri, 2019)	This paper presents the first study estimating the climate sensitivity and potential production of Proso millet using a crop modeling approach. The results of the C3MP study reveal that Proso millet yields increase with up to a 2°C temperature rise in wetter conditions but decrease with additional warming. A 1°C temperature increase in Proso millet growing areas results in a 5-10% yield reduction with no change in rainfall. Projections for future climate, based on 20 General Circulation Models (GCMs) under different emissions scenarios (RCP4.5 and RCP8.5), indicate a clear increase in annual and seasonal temperatures by the mid-21st century. The study models suggest the possibility of a wetter future for Proso millet growing areas, particularly under the RCP4.5 (85% of GCMs) and RCP8.5 (75% of GCMs) scenarios. The study also examines multiple Proso millet accessions (L_1, L_11, L_12, L_14, and L_25) and finds that their yields do not significantly deviate from baseline yields under both emission scenarios. It identifies potential areas	The text does not provide specific information about potential limitations or challenges faced during the study. Although it discusses the differences in Proso millet yield behavior across climatic zones, it doesn't delve into the specific climatic zones or regions examined in the study.	Presents the first study to estimate climate sensitivity and potential production of Proso millet using crop modeling, contributing to the understanding of this crop's response to climate change. Highlights the impact of temperature and rainfall changes on Proso millet yields, providing insights into its adaptability under varying climatic conditions. Projects future climate scenarios and the potential for a wetter climate in Proso millet growing areas. Demonstrates that different Proso millet accessions perform comparably to baseline yields under varying emission scenarios. Identifies potential areas for Proso millet cultivation under both historical and future climates. Provides evidence of Proso millet's suitability and resilience in low-input agricultural systems, which may be crucial for future agricultural planning in the context of climate change.

	for Proso millet cultivation under both historical (1980-2009) and future climates, showing varying yield behaviors across different climatic zones. Proso millet, primarily grown in low-input agricultural systems, demonstrates resilience and adaptability under changing climate conditions, particularly in contrast to other key crops like paddy that are expected to experience yield reductions.		
(Sandhya et al., n.d.)	The study examines data mining methods for forecasting climate and demonstrates their potential to replace conventional meteorological techniques. Preprocessing, clustering, prediction, and classification are just a few of the algorithms that have been found to be effective at forecasting weather phenomena. Accuracy increases initially with larger training sets but declines over time. The suggested model performs admirably when managing short-term energy resources. The development of a hybrid system for greater accuracy and the	The text mentions the creation of a hybrid system and its potential application in thunderstorm forecasting, but it doesn't go into detail about the difficulties or intricacies involved in these improvements. It doesn't go into specifics about the data mining or preprocessing methods used in the study.	shows how data mining can be used to predict the climate. Identifies appropriate algorithms and studies the effect of training set size on accuracy. Provides a workable model for managing short-term energy resources. Suggests future improvements, such as hybrid systems and broader applications for weather prediction.

	expansion of applications to forecast thunderstorms and similar events are potential future improvements.		
(Kamatchi and Parvathi, 2019)	Given the complexity of climate dynamics and climate prediction theories, weather prediction is a difficult field in technology and science. The study focuses on using artificial neural networks (ANN) to forecast the weather. It uses techniques like prediction, recommendation, and classification. The study employs Case-Based Reasoning (CBR) in combination with ANN regularization to increase the recommender system's success rate. The use of various regression models is anticipated to improve prediction accuracy in the future. The weather prediction model used in this study performs pattern recognition of meteorological parameters in a small geographic area, achieving impressive	Although regression models will improve prediction accuracy in the future, the text gives no specifics about these models. The size of the geographic area under study and the precise meteorological parameters are not specified.	Uses artificial neural networks to overcome the difficulties associated with weather prediction. Makes use of classification, suggestion, and prediction techniques. Increases the recommender system's success rate through ANN regularization and a hybrid strategy involving CBR. Indicates potential future advancements in regression model-based prediction accuracy. Exhibits exceptional performance and logical accuracy in forecasting weather for small geographic areas.

	performance and logical accuracy.		
(Chana et al., 2023)	In order to help farmers make decisions, the paper investigates the use of IoT, machine learning, and weather forecasts for crop prediction. Using the Random Forest algorithm, it creates an architecture and IoT prototype for data collection and achieves high accuracy (99%). Recommendations are made by expert systems, and predictions are occasionally affected by weather forecasts. The goals of the study are validated by actual field tests. The dataset will be expanded, and the weather forecast period will be prolonged.	The paper mentions plans to lengthen the weather forecast period and widen the dataset, but it makes no mention of any particular obstacles or potential problems in making these improvements. It doesn't say how many local towns or types of crops were at first included in the dataset.	Examines the use of machine learning and IoT to predict crops. Creates a reliable forecasting system. Shows how weather predictions affect predictions of crop yields. Uses field tests to confirm the study's goals. Suggests potential upgrades.

Table 2 Existing Work

2.5 Technological Review

2.5.1 Climate Data Analysis

Climate-informed agriculture is based on the analysis of climate data. Effective crop selection requires utilizing data on soil properties, weather trends, and other pertinent environmental factors. Farmers can be empowered by a mobile app that incorporates sophisticated climate data analysis by offering insights tailored to their unique situation and needs. However, it's important to take into account any potential restrictions that might affect accuracy, such as the quality of the data and the model parameters Wimalasiri (2019).

2.5.2 User-Friendly Agricultural Apps

A key element in the uptake and influence of agricultural mobile apps is their ease of use. The success of such apps can be determined by factors like usability, accessibility, and the integration of real-time data. The ClimateCrop Advisor app aims to provide farmers with an easy-to-use and flexible tool that helps them make informed decisions about their crops by taking care of thes factors.

Encouraging Further Research

The literature review stresses the contributions made by different studies, but it also emphasizes how crucial it is to conduct ongoing research in the area of climate-informed agriculture. Subsequent investigations may concentrate on optimizing the ClimateCrop Advisor application, resolving constraints, and broadening its range of application to guarantee its efficacy in various areas. Additionally, studies can look into the socioeconomic effects of these apps on rural communities and how technology can help farmers become more productive and enhance their standard of living.

2.6 Chapter Summary

One of the most important initiatives to close the current gap in crop recommendation applications is the development of the Climate Crop Advisor. With its ability to solve issues with accuracy, accessibility, and real-time data integration, the app has the potential to completely transform crop selection. The Climate Crop Advisor, which provides farmers with location-specific insights, has the potential to usher in a new era of precision agriculture by greatly boosting productivity and furthering the general objective of sustainable farming practices. This review of the literature demonstrates the urgent need for such a novel solution given how modern agriculture is changing.

CHAPTER 3 : METHODOLOGY

3.1 Chapter Overview

The methodology chapter provides a thorough plan for carrying out your study or project. It describes your chosen research approach (deductive or inductive), methodological preference (mono, multi, or mixed-method), research strategy (data collection methods), time frame, and the research philosophy guiding your data collection and interpretation. Additionally, it explains your intended data collection and analysis procedures and delves into population and sample size issues. This chapter serves as the foundation of your research, ensuring a well-organized and rigorous approach to achieving your research objectives.

3.2. Research methodology

Layer	What is being using	Why you are using it
Philosophy	Positivism - quantitative	The choice of research philosophy guides our approach to data collection and analysis. In the context of your proposal, positivism is selected to quantitatively analyze climate data, treating climate variables as numerical values. This philosophy ensures that research outcomes are based on objective, factual data. It aligns with the quantitative nature of climate data and the need to provide farmers with accurate crop recommendations.
Approach	Deductive	The deductive approach is employed because your research aims to test the applicability of existing machine learning models and algorithms for climate prediction. It begins with established theories or models (in this case, machine learning algorithms) and assesses their effectiveness in predicting climate conditions. This approach is suitable for validating the utility of these models in your context.
Methodological choice	Mono Method - Quantitative	A mono-method approach, specifically quantitative research, is selected to maintain consistency with positivism and ensure the use of precise numerical data. The aim is to create a data-driven mobile app, and quantitative methods provide the means to analyze climate data and develop accurate crop suggestions.
Strategy	Survey, Experiment	The data collection strategy involves surveys and experiments. Surveys are used to gather quantitative data from farmers regarding their crop decisions and climate conditions. Experiments may be conducted to assess the effectiveness of the machine learning algorithms in predicting climate patterns. This strategy aligns with the research objective of

		understanding farmers' needs and validating the app's performance.
Time Horizon	Cross section	Cross-sectional data collection is chosen because it allows for the collection of data at a single point in time, which is suitable for understanding the current climate conditions and farmers' crop choices. This aligns with the need to provide real-time crop recommendations through the mobile app.
Data Collection and Analysis	Population size, Sample size, Data collection methods (surveys, experiments), Data analysis techniques (machine learning algorithms)	The decisions here relate to determining the population (farmers), sample size, and the methods for data collection and analysis. Large-scale surveys are conducted to obtain data from a substantial number of farmers. Experiments are utilized to evaluate machine learning algorithms' performance. Data analysis involves applying machine learning techniques to climate data. These choices enable the development of a robust mobile app that serves farmers effectively.

Table 3Research methodology

3.3. Development methodology

a. What is the life cycle model and why?

Implementing a life cycle model will help make the app development process more efficient and successful by ensuring that each step is well thought out and carried out.

b. Design Methodology

SSADM and OOAD are both functional. However, OOAD might be more appropriate given that your mobile app has a variety of components (objects) that must function properly as a whole. Making a complex system like a mobile app is well suited to OOAD's emphasis on reusable building blocks. It's similar to using Lego pieces to create a special structure that meets the requirements of your project.

c. Evaluation methodology

Using benchmarking and evaluation statistics, can ensure that app is performing as it should. It's comparable to making sure that it is superior to others in terms of taste, preparation time, and ease. Knowing if your app stands out and accomplishes your objectives is helpful.

3.4. Project management methodology

a. Gantt Chart

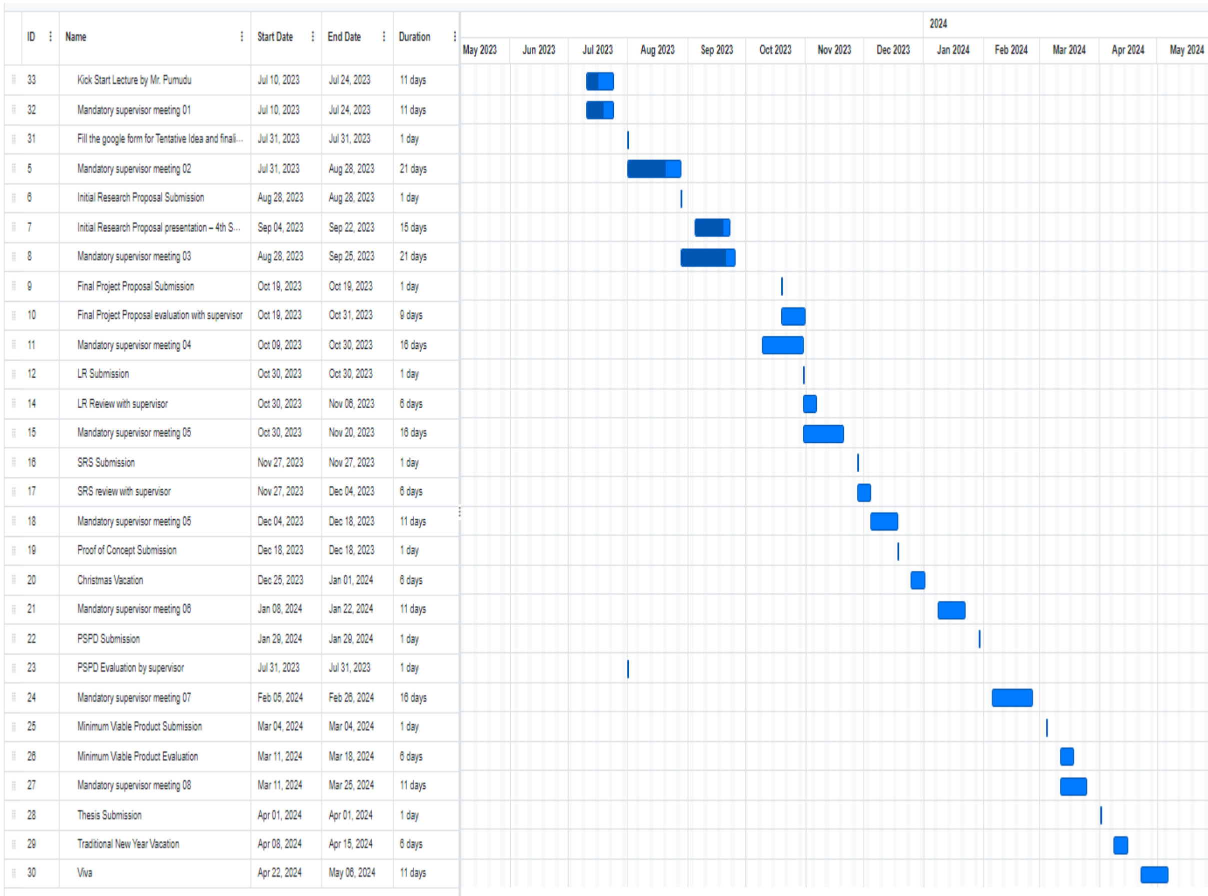


Figure 2 Research plan described in a Gantt chart. (Self Composed)

b. Deliverables, milestones and dates of deliverables

Deliverables	Delivery Date
Initial Research Proposal	1st September 2023
Final Project Proposal	5th October 2023
Literature Review	31st October 2023

Software Requirement Specification	27th November 2023
Proof of Concept	21st December 2023
PSPD	1st February 2024
Minimum Viable Product	7th March 2024
Thesis	4th April 2024

Table 4 Project deliverables and dates

c. Resource requirements

i. Hardware requirements

- High-end computers for testing and developing apps
- Mobile devices for testing and verifying user experience

ii. Software requirements

- Tools for development (IDEs, version control)
- (Python, R) data analysis software
- Libraries for machine learning (TensorFlow, Scikit-learn)
- Platforms for creating mobile apps (Android Studio, Xcode)

iii. Skills requirements

- App development (using languages like Swift and Java)
- Data analysis and science
- Expertise in machine learning
- Design for user experience (UX)
- Know-how in the agricultural domain

iv. Data Requirements

- Data from historical and current climate databases
- Databases of crop data and agronomic information

d. Risk Management

Risk Item	Severity	Frequency	Mitigation Plan
Technical challenges	**5**	**5**	Continuous monitoring and troubleshooting during field research studies; regular inspection and bug-fixing during the development time.
Incorrect data	**5**	**4**	Thorough cross-referencing and data validation; use of reputable and trustworthy data sources; and routine updates to guarantee data accuracy.
User disagreement	**5**	**1**	Farmers should be involved in the design process, receive thorough training and support, and feedback should be continuously gathered for iterative improvements.

Table 5 - Risk Management

Conclusion

One encouraging step in filling the research void in climate-informed agriculture is the creation of the ClimateCrop Advisor app. It offers the potential to transform agricultural practices and advance sustainability by giving farmers, governments, and agribusinesses a scalable, user-friendly, and data-driven tool. The app has a lot of potential, but it's important to recognize the drawbacks that the literature review pointed out. These drawbacks highlight the necessity of giving careful thought to the app's development, data quality, and scalability in order to guarantee its success in practical applications. However, the contributions from the different studies covered in this literature review show how important it is to connect agricultural research with real-world applications. The ClimateCrop Advisor app provides farmers with a glimmer of hope as they navigate the challenges of making climate-informed crop selections, given the unpredictable nature of climate change.

Agriculture and technology will inevitably converge, and this exciting new frontier is embodied by the app. Innovation and continuous research and development are the keys to addressing today's agricultural challenges, ensuring food security, and advancing sustainability in the face of a changing climate. The way forward is obvious: adopting technology and data-driven insights in agriculture is not merely a choice; it is essential to securing a robust and fruitful future.

References

Dahiphale, D., Shinde, P., Patil, K., Dahiphale, V., 2023. Smart Farming: Crop Recommendation using Machine Learning with Challenges and Future Ideas (preprint). https://doi.org/10.36227/techrxiv.23504496.v1

Johnson, D., Almaraz, M., Rudnick, J., Parker, L.E., Ostoja, S.M., Khalsa, S.D.S., 2023. Farmer Adoption of Climate-Smart Practices Is Driven by Farm Characteristics, Information Sources, and Practice Benefits and Challenges. Sustainability 15, 8083. https://doi.org/10.3390/su15108083

Beveridge, L., Whitfield, S., Challinor, A., 2018. Crop modelling: towards locally relevant and climate-informed adaptation. Climatic Change 147, 475–489. https://doi.org/10.1007/s10584-018-2160-z

Adamides, G., Kalatzis, N., Stylianou, A., Marianos, N., Chatzipapadopoulos, F., Giannakopoulou, M., Papadavid, G., Vassiliou, V., Neocleous, D., 2020. Smart Farming Techniques for Climate Change Adaptation in Cyprus. Atmosphere 11, 557. https://doi.org/10.3390/atmos11060557

Cordell, D., Esham, M., Dominish, E., Jacobs, B., 2017. Towards phosphorus and climate smart agriculture (PACSA) in Sri Lanka.

Wimalasiri, E.M., Ashfold, M.J., Jahanshiri, E., Walker, S., Azam-Ali, S.N., Karunaratne, A.S., 2023. Agro-climatic sensitivity analysis for sustainable crop diversification; the case of Proso millet (Panicum miliaceum L.). PLoS ONE 18, e0283298. https://doi.org/10.1371/journal.pone.0283298

Ratnayake, S.S., Kariyawasam, C.S., Kumar, L., Hunter, D., Liyanage, A.S.U., 2021. Potential distribution of crop wild relatives under climate change in Sri Lanka: implications for conservation of agricultural biodiversity. Current Research in Environmental Sustainability 3, 100092. https://doi.org/10.1016/j.crsust.2021.100092

Wimalasiri, E., 2019. Modelling the climate sensitivity of proso millet (panicum miliaceum L.) in Sri Lanka.

Sandhya, P., Vidhya, S., Sasilatha, T., n.d. CROPS RECOMMENDATION BASED ON SOILS AND WEATHER PREDICTION.

Kamatchi, S.B., Parvathi, R., 2019. Improvement of Crop Production Using Recommender System by Weather Forecasts. Procedia Computer Science.

Chana, A.M., Batchakui, B., Nges, B.B., 2023. Real-Time Crop Prediction Based on Soil Fertility and Weather Forecast Using IoT and a Machine Learning Algorithm. AS 14, 645–664. https://doi.org/10.4236/as.2023.145044

Chen, L., Han, B., Wang, X., Zhao, J., Yang, W., Yang, Z., 2023. Machine Learning Methods in Climate Prediction: A Survey. https://doi.org/10.20944/preprints202309.1764.v1

Shin, M., Hwang, S., Kim, J., Kim, B., Jung, J.-S., 2023. A Study on Analyses of the Production Data of Feed Crops and Vulnerability to Climate Impacts According to Climate Change in Republic of Korea. Applied Sciences 13, 11603. https://doi.org/10.3390/app132011603

Shem Juma, G., Kelonye Beru, F., 2021. Prediction of Crop Yields under a Changing Climate, in: Swaroop Meena, R. (Ed.), Agrometeorology. IntechOpen. https://doi.org/10.5772/intechopen.94261

Ismaila Kolawole Oshodi, 2023. DEVELOPMENT OF MACHINE LEARNING ALGORITHMS FOR IMPROVING CROP YIELD PREDICTION by ISMAILA OSHODI. https://doi.org/10.13140/RG.2.2.35258.57281

Zhao, Y., Xiao, D., Bai, H., Tang, J., Liu, D.L., Qi, Y., Shen, Y., 2022. The Prediction of Wheat Yield in the North China Plain by Coupling Crop Model with Machine Learning Algorithms. Agriculture 13, 99. https://doi.org/10.3390/agriculture13010099

Zhao, Y., Xiao, D., Bai, H., Liu, D.L., Tang, J., Qi, Y., Shen, Y., 2022. Climate Change Impact on Yield and Water Use of Rice–Wheat Rotation System in the Huang-Huai-Hai Plain, China. Biology 11, 1265. https://doi.org/10.3390/biology11091265

Tékété, M.L., Salifou Sissoko, Korotimi Théra, Sarra, M., Mamoutou Kouressy, Niaba Témé, Alfousseiny Maïga, Jean-François Rami, Samaké, M., Mahamadou Diakité, Doumbia, M., Aliou Sissoko, Sékouba Sanogo, Sayon Kamissoko, Ankounidjou Yebedié, Baloua Nebie, Vaksmann, M., 2023. Climate change impacts on sorghum adaptation in Mali Climate modeling. https://doi.org/10.13140/RG.2.2.13261.82409