

****GRADUATION PROJECT – I****

****MIDTERM REPORT****

AgroSoil

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**ABSTRACT (min 1000 characters)**

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| This project focuses on the development of an agricultural crop recommendation system based on soil analysis, utilizing machine learning techniques to analyze soil parameters and provide optimal crop suggestions. Agriculture plays a vital role in global food security, and the efficiency of crop production directly impacts economic growth and sustainability. However, selecting the right crop for a specific soil type remains a challenging task, especially for farmers with limited resources and expertise.  The system takes key soil characteristics such as pH level, nitrogen (N), phosphorus (P), potassium (K), organic matter, and moisture content as inputs. Using these parameters, a trained machine learning model predicts the most suitable crops for the given soil. The project aims to assist farmers in making informed decisions by analyzing soil health and matching it with crop requirements, thereby improving agricultural productivity.  A web-based interface is developed to make the system accessible and user-friendly. Users can input soil data through a form, and the system outputs the top recommended crops, along with additional details such as ideal temperature, water requirements, fertilizer requirements for each crop. The interface is designed in Turkish to support native agriculture.  The model is trained on a dataset containing information on various crops and their corresponding soil compatibility. This dataset is carefully curated to include a wide range of crops, fruits and vegetables. By leveraging supervised learning algorithms, the system achieves high accuracy in crop prediction, optimizing recommendations based on regional and environmental factors.  This project addresses the growing need for precision agriculture by providing a scalable, data-driven solution that empowers farmers to utilize their resources efficiently. This initiative holds the potential to revolutionize agricultural practices, promote sustainability, and contribute to native food security. |
| **Keywords: Soil analysis, agriculture, prediction model, machine learning, sustainability** |

1. **INTRODUCTION (min 5000 characters)**

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| Agriculture plays an important role in sustaining human life, providing food, raw materials, and employment to billions of people worldwide. As global populations grow and the effects of climate change intensify, ensuring sustainable agricultural practices has become more critical than ever. Efficient resource management and improved decision-making in agriculture are essential to meet the rising demand for food while minimizing environmental impact. This project, which focuses on developing a machine learning-based agricultural crop recommendation system, aims to address these challenges by using technology to optimize crop selection based on soil properties.  The selection of suitable crops for specific soil types is a critical factor in achieving higher yields, reducing resource wastage, and minimizing environmental degradation. Farmers often rely on traditional knowledge or external consultations to decide which crops to plant. However, these methods may not fully account for variations in soil characteristics, local climate conditions, and other critical factors. This project introduces a systematic, data-driven approach to assist farmers in making more informed crop decisions, ultimately improving productivity and sustainability.  At the core of our project is the integration of machine learning algorithms to analyze soil data and predict optimal crops. Soil characteristics such as pH, nitrogen, phosphorus, potassium levels, organic matter content, and moisture are key determinants of soil health and fertility. By analyzing these parameters, the proposed system aims to recommend crops that are not only compatible with the soil but also align with local agricultural practices. The use of historical data and advanced predictive models ensures accuracy and reliability in recommendations.  The project aligns with sustainable development goals, especially those related to food security, responsible resource usage, and climate action. By supporting efficient land use and reducing dependency on chemical fertilizers and pesticides, the system supports environmentally friendly farming practices. Furthermore, it empowers farmers with actionable insights, fostering economic stability and resilience against challenges such as climate variability and market fluctuations.  The implementation of this project involves several key steps: data collection, preprocessing, model development, evaluation, and deployment. Soil and crop datasets are collected and cleaned to remove inconsistencies, ensuring the data's quality. The machine learning model is trained on this dataset, using the Random Forest Classifier algorithm. Evaluation metrics such as accuracy, precision, and recall are employed to measure the model's performance. Once validated, the system is deployed as a web application, providing farmers with a user-friendly interface to input soil parameters and receive crop recommendations.  In addition to its technical aspects, the project incorporates ethical and legal considerations. The protection of user data is a top priority, particularly if the system is extended to include personalized farmer profiles. Compliance with data privacy regulations, such as Turkey's Kişisel Verilerin Korunması Kanunu (KVKK), ensures that user information is handled responsibly. Moreover, intellectual property rights are respected by ensuring that all data and algorithms used in the system are legally sourced and properly licensed.  The project also addresses broader societal and environmental challenges. Agriculture is a major contributor to greenhouse gas emissions, deforestation, and water usage. By optimizing crop selection and reducing resource wastage, this system contributes to mitigating the environmental footprint of farming. Additionally, the adoption of precision agriculture technologies promotes a shift toward sustainable practices, benefiting both farmers and the ecosystem.  To enhance its utility, the system can be integrated with other technologies, such as weather forecasting tools, market price analytics, and precision farming equipment. For example, incorporating real-time weather data could enable dynamic recommendations that adjust to changing environmental conditions. Similarly, insights into market trends could help farmers make economically viable decisions, balancing productivity with profitability.  The project's scope extends beyond local benefits. As a modular and scalable system, it has the potential to be adapted to different regions and countries with varying agricultural conditions. By incorporating region-specific datasets and regulatory frameworks, the system can provide localized solutions, making it a versatile tool for global agricultural challenges.  In summary, this project represents a significant step toward modernizing agriculture through technology. By using machine learning to provide data-driven crop recommendations, it addresses critical issues of food security, resource management, and environmental sustainability. The project's outcomes have the potential to empower farmers, reduce environmental impact, and contribute to a more resilient agricultural sector. As technology continues to evolve, this initiative underscores the importance of innovation in ensuring a sustainable future for agriculture and society at large. |

1. **REALISTIC CONSTRAINTS AND CONDITIONS**

1.1. **Sustainable Development Goal (min 1000 characters)**

Discuss the relationship between your project topic and the sustainable development goal you chose in section 13.

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| The chosen Sustainable Development Goal (SDG) for this project is Goal 15: Life on Land, which emphasizes the importance of protecting, restoring, and promoting the sustainable use of terrestrial ecosystems. This includes combating desertification, halting land degradation, and preserving biodiversity. The relationship between our project and this goal is rooted in the optimization of agricultural practices to ensure sustainable land use and minimize environmental degradation.  Agriculture is one of the most significant drivers of land degradation and habitat loss globally. Unsustainable farming practices, such as overuse of chemical fertilizers and monocropping, deplete soil nutrients, disrupt ecosystems, and contribute to biodiversity loss. This project addresses these challenges by employing a machine learning-based system to recommend suitable crops based on soil analysis. By aligning crop choices with soil health, the system minimizes the need for excessive chemical inputs, thus preserving the natural fertility of the land and promoting ecosystem balance.  The project also aligns with the goal's focus on combating the impacts of climate change on terrestrial ecosystems. Agriculture significantly contributes to greenhouse gas emissions through practices like deforestation, land conversion, and excessive fertilizer use. By promoting crop choices that enhance carbon sequestration and reduce emissions, the system supports climate-resilient agricultural practices.  Additionally, the project incorporates the principles of precision agriculture, enabling farmers to make data-driven decisions. This reduces resource wastage, such as water and fertilizers, further supporting the sustainable use of terrestrial ecosystems. |

* 1. **Effects on Health, Environment and the Problems of the Age Reflected in the Field of Engineering (min 1000 characters)**

Discuss the impact of your project on health, environment and safety in universal and social dimensions and the problems of the age reflected in the field of engineering.

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| The project has significant implications for health, the environment, and contemporary engineering challenges. First, by recommending the most suitable crops for specific soil conditions, it promotes sustainable farming practices that reduce the dependency on chemical fertilizers and pesticides, which are known to contaminate soil and water resources and harm human health.  From an environmental perspective, the project minimizes agricultural pollution by encouraging the efficient use of natural resources. This aligns with global efforts to combat environmental degradation and address issues such as soil erosion, deforestation, and biodiversity loss. Additionally, by optimizing water usage, the project contributes to mitigating the impacts of water scarcity, one of the most pressing issues of our time.  In the field of engineering, the project reflects the growing importance of data-driven solutions in addressing complex problems. By integrating machine learning models with real-world agricultural data, the system demonstrates how technology can tackle global challenges like food insecurity and climate change. It also highlights the role of engineers in designing accessible and scalable systems that benefit diverse populations, bridging the gap between technology and sustainability. |

* 1. **Legal Consequences (min 1000 characters)**

Discuss the legal consequences of your project.

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| This project must comply with Turkey's legal regulations, particularly those governed by the Kişisel Verilerin Korunması Kanunu (KVKK), to ensure ethical use and data privacy. While the current system primarily uses soil and crop data, any future inclusion of farmer-specific information must adhere to KVKK requirements, such as obtaining explicit consent for data collection, ensuring data security, and limiting data usage to its intended purpose. Safeguarding user privacy is essential to maintaining compliance and trust.  Another key consideration involves intellectual property rights. The machine learning model and dataset used in the project must be original or properly licensed to prevent potential infringement issues.  The system's recommendations must also be clear and transparent to avoid misleading users. Legal disclaimers should state that predictions are based on existing data and are probabilistic, not guarantees of success. Such measures can help mitigate liability risks and maintain ethical standards.  In Turkey, agricultural practices are subject to specific regulations regarding the use of fertilizers, pesticides, and other inputs. The system must incorporate these legal requirements to ensure that its recommendations are compatible with local agricultural laws. For example, certain chemicals may be prohibited, or their use may be limited to specific crops or soil conditions. Aligning the system with these legal frameworks enhances its credibility and supports its safe adoption in different regions.  By addressing these legal aspects, the project not only ensures compliance with Turkish regulations but also builds a foundation for ethical and sustainable usage, promoting trust among users and stakeholders. |

1. **LITEARTURE ANALYSIS (min 8000 characters)**

Perform a literature analysis on your project topic to summarize the state-of-the-art in the field. Explain similar applications. Use proper in-text citations and list them in the references section.

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| Agricultural crop recommendation based on soil analysis has become a crucial focus in modern agricultural engineering due to its potential to enhance productivity, promote sustainable farming practices, and address food security challenges. With the increasing application of data science, machine learning, and soil analytics, researchers and practitioners have developed several innovative systems to optimize crop selection. This section provides a comprehensive review of the literature, summarizing the state-of-the-art technologies, methodologies, and applications. It also explores the challenges, gaps, and opportunities for improvement in the field.  Overview of Crop Recommendation Systems  Crop recommendation systems aim to assist farmers in selecting the most suitable crops for specific soil and climatic conditions. These systems analyze key factors such as soil composition, nutrient levels, weather patterns, and market dynamics to make informed recommendations. Traditional methods, which relied on expert knowledge and manual assessments, often failed to scale across diverse agricultural contexts and lacked the precision necessary to address modern challenges like climate variability and resource constraints.  Recent advancements in computational power and the availability of large-scale datasets have enabled the application of machine learning algorithms to develop more sophisticated and reliable crop recommendation systems. These systems are transforming the agricultural landscape by reducing resource wastage, improving crop yields, and ensuring the long-term sustainability of farming practices.  State-of-the-Art in Crop Recommendation Systems  1- Machine Learning Techniques  Machine learning (ML) serves as the backbone of most modern crop recommendation systems. Algorithms like Decision Trees, Random Forest, Support Vector Machines (SVM), and Artificial Neural Networks (ANN) are widely used for their ability to process complex and non-linear data relationships.   * + Random Forest: Studies have demonstrated that Random Forest excels in scenarios requiring predictions based on multiple soil features, including pH, organic content, and macro-nutrients like nitrogen, phosphorus, and potassium (Kumar et al., 2020). The algorithm’s robustness against over-fitting makes it particularly suited for agricultural datasets.   + Artificial Neural Networks (ANNs): ANNs are employed to model complex, non-linear interactions between soil characteristics and crop yields. They have been proven effective in scenarios requiring high accuracy, such as predicting the impact of micro-nutrients on crop growth (Gopal et al., 2021).   + Ensemble Learning: Ensemble methods, which combine multiple machine learning models, are increasingly popular in crop recommendation systems. For instance, Gradient Boosting combined with Random Forest has been shown to enhance prediction accuracy under variable climatic conditions (Smith et al., 2021).   2- Big Data and Cloud Computing  The integration of big data analytics and cloud computing has enabled real-time and large-scale implementation of crop recommendation systems. Systems such as Agri-Sense and SmartFarms utilize these technologies to process data from IoT sensors, satellites, and weather stations.  3- Deep Learning Applications  Deep learning models, such as Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, are gaining traction in agriculture. CNNs are particularly effective in analyzing remote sensing data to assess soil moisture levels, while LSTMs can predict long-term crop productivity based on historical data trends (Zhang et al., 2022).  Similar Applications in Agriculture  Several crop recommendation systems and projects have been developed globally to address the challenges of sustainable farming.  1- Bhoochetana Project (India)   * + Focused on improving soil health and agricultural productivity by providing soil health cards and crop-specific recommendations. This project highlighted the importance of soil testing as a precursor to effective crop recommendations.   2- KrishiMitra (India)   * + A mobile application offering crop and fertilizer recommendations based on soil test results, weather forecasts, and market prices. The app has been successful in bridging the information gap for small-scale farmers, although limited smartphone access remains a challenge.   3- Agri-Sense (United States)   * + A cloud-based platform leveraging IoT sensors and machine learning to provide crop recommendations and irrigation schedules. The system emphasizes resource optimization and precision farming.   4- SmartFarms (Europe)   * + Combines satellite imagery, soil sensors, and machine learning models to offer detailed insights into crop suitability, pest detection, and yield estimation. It represents a comprehensive approach to modern agriculture.  Challenges and Gaps in the Field Despite significant advancements, several challenges persist in developing and implementing crop recommendation systems:  1- Data Scarcity   * + Many regions lack the infrastructure for soil testing, resulting in incomplete datasets. Without high-quality data, machine learning models struggle to make accurate recommendations.   2- Localization Issues   * + Most existing systems are designed for specific regions or crops, limiting their applicability in diverse agricultural environments. Developing models that can generalize across regions remains a key challenge.   3- Adoption Barriers   * + Farmers in developing regions often face obstacles such as limited access to technology, lack of technical expertise, and financial constraints. User-friendly interfaces and training programs are necessary to drive adoption.   4- Sustainability Concerns   * + Ensuring that recommendations align with sustainable farming practices, such as crop rotation and reduced chemical usage, is critical. Many systems fail to account for long-term soil health and environmental impacts.   Our Contribution  The proposed project aims to address these challenges by developing a machine learning-based crop recommendation system tailored to Turkish agricultural conditions. Key features include:   * Localized Data Integration: Leveraging national soil datasets to ensure relevance and accuracy. * User-Friendly Interface: Developing a web-based platform accessible to farmers, policymakers, and agricultural experts. * Sustainability Focus: Incorporating recommendations for crop rotation, organic farming, and resource optimization to promote sustainable agriculture. * Legal and Ethical Compliance: Adhering to Turkey's KVKK regulations and ensuring data privacy.   Conclusion  Literature analysis reveals that crop recommendation systems have made significant strides in improving agricultural productivity and sustainability. However, challenges such as data scarcity, localization, and farmer adoption remain barriers to widespread implementation. By addressing these issues, the proposed project seeks to contribute to the advancement of this field, offering a tailored solution for Turkish agriculture and promoting sustainable farming practices on a global scale.  References  1- Kumar, R., Singh, A., & Gupta, V. (2020). Random Forest in Agricultural Predictions. Journal of Sustainable Agriculture.  2- Gopal, S., Ramesh, K., & Verma, T. (2021). Artificial Neural Networks for Crop Yield Prediction. International Journal of Machine Learning in Agriculture.  3- Smith, J., Brown, P., & Wilson, L. (2021). Ensemble Learning in Precision Agriculture. Machine Learning Applications in Agriculture.  4- Zhang, L., & Li, Y. (2022). Deep Learning in Soil and Crop Analysis. IEEE Transactions on Agricultural Systems.  5- Reddy, S., & Patel, K. (2019). KrishiMitra: A Mobile-Based Crop Recommendation System. International Journal of Agricultural Research.  6- Johnson, T., & Lee, D. (2021). Agri-Sense: IoT and Machine Learning for Precision Agriculture. IEEE Transactions on Agricultural Systems.  7-Peters, M., & Anderson, J. (2020). SmartFarms: Leveraging Satellite Data for Sustainable Agriculture in Europe. European Journal of Agricultural Innovation. |

1. **STANDARDS TO BE USED (min 1000 characters)**

Explain the engineering standards you plan to use in the development of your project.

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| Engineering standards play a critical role in ensuring that the project is reliable, efficient, and aligned with best practices. In this project, several key standards will be applied:  1- Data Collection and Management: Standards such as the FAO Guidelines for Soil Description will ensure consistent and accurate soil data collection. Additionally, ISO 19115 for geographic metadata will facilitate the organization and interoperability of data.  2- Software Development: The project will adhere to ISO/IEC 12207 to manage the software lifecycle efficiently, and IEEE 29119 to ensure rigorous testing of the web application and machine learning algorithms.  3- Machine Learning: Compliance with ISO/IEC 20546 will provide a structured approach to processing large soil and crop datasets.  4- Legal and Ethical Compliance: The project will align with KVKK, Turkey’s data protection law, to ensure privacy and security in handling sensitive user data.  By using these standards, the project ensures quality, sustainability, and compliance with engineering and legal norms. |

1. **APPROACHES, TECHNIQUES, AND TECHNOLOGIES TO BE USED (min 6000 characters)**

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| The agricultural crop recommendation project, based on soil analysis, requires a multidisciplinary approach involving advanced data processing, machine learning (ML), and web application development. This section outlines the methodologies, techniques, and technologies that will be employed throughout the project to achieve optimal results and user engagement.  1. Data Collection and Preprocessing  The dataset used for this project was meticulously crafted to ensure high-quality inputs for training the machine learning model. Given the unavailability of a comprehensive dataset that encompasses detailed soil compatibility information for a wide range of crops, the dataset was manually compiled. The data collection process involved extensive research from agricultural sources, including scientific journals, government agricultural databases, and trusted online resources.  1.1 Data Collection  Key soil parameters such as pH levels, nitrogen (N), phosphorus (P), potassium (K), organic matter, and moisture content were identified as crucial factors influencing crop growth. The following steps were undertaken:  Optimal Range Identification: For each crop, the data gathered on the optimal ranges of these soil parameters. This included values for soil pH, macronutrient requirements, and organic matter content.  Additional Factors: Information on ideal temperature, water requirements, and recommended fertilizers for each crop was also collected to provide a more comprehensive recommendation.  Sources: Data was collected from agricultural research papers, government publications, and online resources specific to Turkish agriculture to ensure regional relevance.  1.2 Dataset Structure  The compiled data was structured into a tabular format, where each row represented a crop and its corresponding optimal soil characteristics. Key columns included:   * Crop Name * pH Range * Nitrogen (N) Level * Phosphorus (P) Level * Potassium (K) Level * Organic Matter Content * Humidity Level   1.3 Data Preprocessing  Once the dataset was compiled, preprocessing steps were performed to prepare the data for training the machine learning model:  Handling Missing Data: Some crops had incomplete information for certain parameters. Missing values were estimated based on similar crop characteristics or expert knowledge.  Normalization: Soil parameters were normalized to ensure uniformity across features and improve model performance.  Train-Test Split: The dataset was divided into training and testing subsets to evaluate model performance.  This manually curated dataset forms the foundation of the project, offering a robust basis for developing an accurate and reliable agricultural crop recommendation system. By integrating region-specific data and preprocessing techniques, the system is tailored to support farmers in Turkey effectively. 2. Machine Learning Techniques2.1 Model Selection The recommendation system will utilize supervised ML algorithms such as:   * Decision Trees: For their interpretability in displaying how features contribute to crop suitability. * Random Forests: To improve accuracy by aggregating decisions from multiple trees. * Support Vector Machines (SVM): To handle non-linear relationships between soil features and crop suitability.  2.2 Hyperparameter Tuning To maximize model accuracy, techniques such as grid search and random search will be employed to fine-tune hyperparameters like tree depth, learning rate, and regularization parameters. 2.3 Model Evaluation Evaluation metrics like precision and accuracy will be used to assess the models. Additionally, k-fold cross-validation will validate the models' robustness across different data splits.  3. Technologies for Data Handling and Model Deployment 3.1 Python for Machine Learning Python will be the primary programming language due to its rich ecosystem of ML libraries, including:   * Pandas and NumPy: For data manipulation and numerical computations. * Scikit-learn: For model implementation and evaluation. * Matplotlib and Seaborn: For data visualization, aiding in feature selection and result interpretation. (to be used)  3.2 Cloud Computing Platforms To handle large datasets and perform computationally intensive tasks, cloud platforms like Google Colab will be utilized. This platform offers GPU acceleration, enabling faster training of ML models. 3.3 Database Integration A structured database, such as MySQL or PostgreSQL, will store soil and crop data for efficient querying during user interactions.  4. Web Application Development 4.1 Frontend Design The web application's user interface will be developed using modern frontend framework, Bootstrap to ensure cross-device compatibility and a clean design. 4.2 Backend Development The backend will be implemented using Flask offering the capability, integration with the trained ML model for real-time crop recommendations. 4.3 API Development RESTful APIs will be created to facilitate seamless communication between the frontend and backend. API will handle user inputs, send soil data for analysis, and retrieve recommendations.  5. Iterative Development and Testing 5.1 Agile Methodology The project will follow an agile approach, ensuring continuous improvement through iterative cycles of development and testing. 5.2 Testing Strategies  * Unit Testing: To validate individual components like data preprocessing scripts and model functions. * Integration Testing: To ensure smooth interaction between the frontend and backend. * User Testing: Real-world soil samples and user feedback will help refine the system.   6. Collaboration Tools 6.1 Version Control Git and GitHub will manage the project’s codebase, ensuring collaborative efficiency and tracking changes. 6.2 Communication Platforms Tools like Teams will facilitate team coordination and task management.  7. Deployment 7.1 Containerization The application will be deployed using Docker to ensure consistency across development and production environments.  In conclusion, the project integrates state-of-the-art techniques and technologies in machine learning and web development. By following this comprehensive approach, the system aims to deliver accurate and user-friendly solutions for agricultural crop recommendations based on soil analysis. |

1. **PROJECT SCHEDULE AND TASK SHARING**

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| **WP No** | **Work Package Name** | **Assigned project staff** | **Time Period (..-.. Week)** | **Success Criteria** |
| 1 | Data Collection and Dataset Setup, Preprocessing and Cleaning | Özgül BAYTEKİN  Sedef ELMAS | Week1 - Week 2 (Starting from 23.09.2024) | Dataset prepared and structured for model training.  All data cleaned, missing values handled. |
| 2 | Use case scenarios. | Sedef ELMAS  Özgül BAYTEKİN | Week 3 | Defining use case scenarios and drawing the diagrams. |
| 3 | Model Selection and Development,  Training and Evaluation | Özgül BAYTEKİN  Sedef ELMAS | Week 4 - Week 6 | A working machine learning model with initial test results.  Model trained, tested, and accuracy improved. |
| 4 | Web Application Development | Sedef ELMAS  Özgül BAYTEKİN | Week 7 – Week 8 | Web application is functional with user interface for testing. |
| 5 | Integration of Model into Web App,  User Testing | Özgül BAYTEKİN  Sedef ELMAS | Week 8 | Machine learning model integrated and working within the app. |
| 6 | Report Preparation | Sedef ELMAS  Özgül BAYTEKİN | Week 9 | Midterm project report prepared. |
| 7 | Json File Updated | Özgül BAYTEKİN  Sedef ELMAS | Week10 - Week12  (starting from 27.11.2024) | The data contained in the json file should be in the correct format for displaying the results on the page. |

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| 8 | Model Training | Sedef ELMAS  Özgül BAYTEKİN | Week13 - Week15 | New model is trained according to the updated dataset. |
| 9 | Backend and Frontend Update | Özgül BAYTEKİN  Sedef ELMAS | Week15 - Week17 | Region selection feature added. |
| 10 | Report Preparation | Sedef ELMAS  Özgül BAYTEKİN | Week18 | Final project report prepared. |

1. **RISK MANAGEMENT**

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| **WP No** | **Risks** | **Risk Management (Plan B)** |
| 1 | Data Quality Issues | |  | | --- | |  |  |  | | --- | |  |   If there are issues with data quality, alternative data sources can be explored, and data cleaning techniques can be applied to ensure the data is suitable for the model. |
| 2 | Model Underperformance | |  | | --- | |  |  |  | | --- | |  |   If the model does not meet the desired accuracy, different algorithms can be tested, and hyperparameter tuning can be performed to improve performance. |
| 3 | Integration Issues | |  | | --- | |  |  |  | | --- | |  |   If there are integration issues between the model and the web application, the integration process can be reviewed step-by-step, and necessary code adjustments can be made. |
| 4 | |  | | --- | |  |   Delays in Data Collection | |  | | --- | |  |  |  | | --- | |  |   If there are delays in data collection, additional resources can be allocated, or the data preparation process can be expedited in parallel to speed up the process. |
| 5 | Project Requirements Changing | |  | | --- | |  |  |  | | --- | |  |   If project requirements change, the scope can be redefined, and a scope management plan can be implemented to minimize the impact of these changes. |
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1. **SYSTEM REQUIREMENTS ANALYSIS**

**7.1. Use Case Model (min 3000 characters)**

Use case model (or functional model) describes the main actors of the system and their main use cases with a UML use case diagram.

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| Actors:   1. Farmer (Primary Actor)    * Inputs soil parameters to get crop recommendations.    * Seeks detailed information about specific crops.    * Makes agricultural decisions based on system recommendations. 2. System Administrator (Secondary Actor)    * Manages the system by updating datasets and training the machine learning model.    * Ensures the system runs efficiently and resolves any technical issues.   Use Cases:  1- Input Soil Data  Actor: Farmer  Description: The farmer enters soil parameters (pH, N, P, K, organic matter, and moisture) into the system using the web-based form.  2- View Crop Recommendations  Actor: Farmer  Description: The farmer views a list of the recommended crops and selects one to view detailed information.  3- Fetch Crop Details  Actor: Farmer  Description: The system retrieves additional details about the selected crop from the json file, including ideal temperature, pH, water needs, and fertilizer requirements.  4- Update Dataset  Actor: System Administrator  Description: The administrator updates the dataset with new information or modifies existing data to improve system accuracy.  5- Train Model  Actor: System Administrator  Description: The administrator retrains the machine learning model using a refined dataset to enhance prediction performance.  6- Manage System  Actor: System Administrator  Description: The administrator monitors and resolves system issues, including managing performance.  Example Scenarios  Scenario 1: Submitting Soil Data   * Fatma, a farmer in Anatolia, wants to know which crops to plant in her field. * She opens the crop recommendation web interface on her tablet. * Fatma enters the pH level, nitrogen, phosphorus, potassium, organic matter percentage, and soil moisture of her field into the form. * She confirms the data and submits it. * The system validates her inputs and forwards them to the prediction engine. * The prediction engine processes the data and recommends the top three most suitable crops. * After a few seconds, the system displays the top three recommended crops along with details like water and fertilizer requirements.   Scenario 2: Updating Crop Information   * Ayşe, the system administrator, notices new research about the water requirements of corn. * Ayşe searches for "corn" in the json file and updates the water requirement details based on the latest data. * She saves the changes and runs a validation check to ensure data consistency.   Scenario 3: Regional Recommendations   * Mehmet, a farmer from Eastern Turkey, wants recommendations specific to his region. * After entering his soil data, he also specifies his region (Eastern Anatolia) in the form. * The prediction engine filters the crop list to include only those that thrive in the cold and dry climate typical of the region. * The system recommends barley and chickpeas, displaying their compatibility scores and growth requirements tailored to the regional context.   Scenario 4: Handling System Errors   * Selin attempts to use the recommendation system but accidentally enters incomplete soil data. * The system detects missing values for nitrogen and phosphorus and displays an error message asking her to complete the input fields. * Selin corrects her input and resubmits the form. * This time, the system processes the data without errors and provides her with crop recommendations. |

**7.2. Object Model (min 3000 characters)**

Object model describes the main objects in the system and their relationships with the help of a UML class diagram.

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| The object model of this system outlines the main components that interact to provide the functionality of the agricultural crop recommendation system. It describes the primary objects and their relationships, which together create a structured framework for data processing, machine learning predictions, and user interactions. Below is a detailed explanation of the system's object model, along with a UML class diagram that visualizes the relationships. Classes and Their Attributes 1-SoilAnalysis This class is responsible for handling soil data input and performing predictions based on the trained machine learning model. It acts as a bridge between the user's input data and the system's prediction logic.  Attributes:   * + - PH: Soil pH value of the soil.     - N: Nitrogen content of the soil.     - P: Phosphorus content of the soil.     - K: Potassium content of the soil.     - ORG: Organic matter percentage of the soil.     - HUM: Humidity percentage of the soil.   Methods:   * + - predict\_soil\_quality(features): Accepts soil features as input and calls the prediction model to determine suitable crops for the analyzed soil sample.     - get\_top\_crops(probabilities): Processes the model's output to identify the top three crops with the highest likelihood.   2-Crop This class represents an agricultural crop and its associated information, such as ideal growing conditions and water requirements. Each instance of this class corresponds to a specific crop.  Attributes:   * + - name: The name of the crop (e.g., Wheat, Sunflower, Beans, Apple).     - ideal\_temperature: The optimal temperature range for the specified crop.     - ideal\_soil\_ph: The optimal soil pH range for the crop.     - water\_requirements: The water requirement level (e.g., Low, Moderate, High).   The number of attributes can increase or decrease depending on the needs of each plant while growing.  Methods:   * + - get\_info(): Returns detailed information about the crop's ideal growing conditions.   3-PredictionModel This class encapsulates the trained machine learning model and its label encoder. It handles the core prediction functionality and provides methods for processing the input data.  Attributes:   * + - model: The machine learning model trained to predict crop suitability.     - label\_encoder: A label encoder for converting crop names to numeric labels and vice versa.     - accuracy: The average accuracy score of the trained model.   Methods:   * + - predict\_proba(features): Returns the prediction probabilities for each crop based on the input soil features.     - load\_model(path): Loads the trained model and the label encoder from the specified file paths.   4-CropStorage This class manages the database of crops stored in a JSON file. It provides methods for loading crop data and retrieving crop-specific details such as ideal temperature range, soil pH, and water requirements.  Attributes:   * + - crop\_info: A dictionary containing crop names as keys and their associated details as values.   Methods:   * + - load\_crop\_data(path): Loads crop information from a JSON file.     - get\_crop\_info(crop\_name): Retrieves information about a specific crop. |

1. **SYSTEM DESIGN**

**8.1. Software Architecture (min 2000 characters)**

Describe the decomposition of your system into subsystems. Use a UML component or package diagram to show your SW architecture.

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**8.2. Hardware Architecture (if exists)**

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**8.3. Persistent Data Management (if exists)**

Persistent data management describes the persistent data stored by the system and the data management infrastructure required for it. This section typically includes the description of data schemes, the selection of a database, and the description of the encapsulation of the database.

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1. **SYSTEM TEST DESIGN (min 5000 characters)**

Design a test to evaluate your system. The test design depends on the project topic (Some possibilities: user evaluation, surveys, performance tests, unit tests, etc.)

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1. **DISCUSSION OF THE RESULTS (min 3000 characters)**

Summarize your study. Discuss the quantitative results obtained by the test you performed in Section 9.

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1. **REFERENCES**
2. **CHOOSE INTERDISCIPLINARY DOMAIN OF YOUR STUDY**

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| Choose an item. |

1. **CHOOSE SUSTAINABILITY DEVELOPMENT GOAL OF YOUR PROJECT**

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| Choose an item. |

1. **SIMILARITY REPORT**

The similarity report obtained from the tools such as ithenticate or Turnitin should be attached to the final report. The required actions will be announced later.

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