ADVANCING HEAT RESILIENCE

B.Sc. (Hons) Degree in Information Technology Specialized in Information Technology

Name	Student ID	Sub Topic
Dissanayaka. D. M. S. M	IT20145552	Heat Vulnerability Index (HVI) specific to Sri Lanka
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Faculty of Computing

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April 2024

DECLARATION

IT20145552 – Dissanayaka. D. M. S. M

I hereby declare that this report, represents my own work. I affirm that this proposal does not incorporate, without acknowledgment, any material previously submitted for a degree or diploma in any other university or institute of higher learning. Furthermore, to the best of my knowledge and belief, it does not contain any material previously published or written by another person, except where acknowledgment is made in the text.

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IT20142728 – Ranawaka. T. D

I declare this is my work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute and to the best of my knowledge it does not contain any material previously written by another person except where the acknowledgement is made in the text.

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ABSTRACT

Heatwaves pose significant challenges to communities worldwide, with Sri Lanka, situated in a tropical climate zone, particularly susceptible to rising temperatures and extreme heat events. To address this, our research endeavors to create a comprehensive solution for resilience against heatwave impacts, focusing on heatwave detection, agricultural solutions, and health impacts.

The Heat Vulnerability Index (HVI) serves as a critical tool for assessing the susceptibility of populations to heat-related hazards. Our study aims to develop an HVI specific to Sri Lanka, drawing upon socio-economic, demographic, and environmental indicators. Methodologically, we employ a multidimensional approach, encompassing data collection, processing, and spatial analysis to identify spatial variations and hotspots of heat vulnerability across different regions.

A mobile application is proposed as part of our solution, providing users with real-time information about heatwave conditions. Leveraging machine learning, the application accurately identifies weather patterns and predicts heatwave occurrences. By analyzing historical weather data, temperature patterns are detected, aiding in the early identification of extreme heat conditions. This application is tailored to the Sri Lankan context, offering specialized features for the local climate.

Furthermore, our research integrates agricultural solutions into the resilience framework. Soil moisture forecasting and crop recommendation play a crucial role in mitigating heatwave impacts on agriculture. Using Google Earth data, we analyze soil moisture variations from 2017 to 2022, providing insights for cultivators to optimize irrigation levels and select suitable crops based on weather conditions.

Overall, our study contributes to a deeper understanding of heat vulnerability dynamics in Sri Lanka and provides actionable insights for disaster preparedness, urban planning, and public health interventions. By combining heatwave detection, agricultural solutions, and health impact assessments, our comprehensive approach aims to enhance community resilience and mitigate the impacts of heatwaves in Sri Lanka

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LIST OF ABBREVIATIONS

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ABREVIATION	DESCRIPTION
HVI	Heat Vulnerability Index
SLIIT	Sri Lanka Institute of Information Technology
GIS	Geographic Information System
GDP	Gross Domestic Product
NGO	Non-Governmental Organization
WHO	World Health Organization
IPCC	Intergovernmental Panel on Climate Change
SDGs	Sustainable Development Goals
SDG	Urban Heat Island
UHI	Non-Communicable Diseases
MSL	Mean Sea Level
GDP	Gross Domestic Product
HDI	Human Development Index
UNFCCC	United Nations Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change
IMD	Indian Meteorological Department
GCM	Global Climate Model
NWP	Numerical Weather Prediction
GFDL	Geophysical Fluid Dynamics Laboratory
VIF	Variance Inflation Factor

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ABREVIATION	DESCRIPTION
SM	Soil Moisture
NDVI	Normalized Difference Vegetation Index
SAR	Synthetic Aperture Radar
MODIS	Moderate Resolution Imaging Spectroradiometer
LSTM	Long Short-Term Memory
SVM	Support Vector Machine
RF	Random Forest
ANN	Artificial Neural Network
IoT	Internet of Things
GIS	Geographic Information System
RMSE	Root Mean Square Error
FAO	Food and Agriculture Organization
NWP	Numerical Weather Prediction
WSN	Wireless Sensor Network
AI	Artificial Intelligence
UAV	Unmanned Aerial Vehicle
ROI	Return on Investment
BMP	Best Management Practices
CSA	Climate-Smart Agriculture

1. INTRODUCTION

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1.1 General Introduction

In recent years, the impacts of climate change have become increasingly pronounced, with rising global temperatures leading to more frequent and intense heatwaves around the world. Sri Lanka, situated in the tropical region of the Indian Ocean, is particularly vulnerable to the adverse effects of extreme heat events. As temperatures continue to rise and heatwaves become more frequent and severe, understanding and addressing heat vulnerability becomes imperative to safeguarding the well-being and resilience of Sri Lanka's population.

The concept of heat vulnerability encompasses a range of factors that influence an individual or community's susceptibility to heat-related hazards. These factors include socio-economic status, demographic characteristics, access to healthcare services, housing conditions, and environmental factors such as urban heat island effects and green infrastructure. Assessing heat vulnerability requires a multidimensional approach that considers the interplay of these factors within specific geographic contexts.

One effective tool for assessing heat vulnerability is the Heat Vulnerability Index (HVI), which provides a quantitative measure of vulnerability by integrating various socio-economic, demographic, and environmental indicators. Developing an HVI specific to Sri Lanka is crucial for identifying vulnerable populations, prioritizing adaptation measures, and informing policy decisions aimed at reducing the impacts of heatwaves.

This report aims to introduce and explore the development of an HVI tailored to the unique socioeconomic, demographic, and climatic conditions of Sri Lanka. Drawing upon existing literature on heat vulnerability assessment methodologies and leveraging available data sources, this research seeks to construct a comprehensive HVI framework that captures the complex dynamics of vulnerability across different regions of Sri Lanka.

By analyzing spatial variations in heat vulnerability and identifying hotspots of vulnerability, this research contributes to a better understanding of the underlying drivers of heat vulnerability in Sri Lanka. The findings of this study are expected to inform evidence-based decision-making processes, enabling policymakers, planners, and public health authorities to implement targeted interventions and enhance the resilience of communities to heat-related hazards.

1.2 Background Literature

Heatwaves represent a significant and increasingly prevalent threat to public health and well-being, exacerbated by the effects of climate change. As global temperatures continue to rise, heat-related hazards pose substantial risks to vulnerable populations, particularly in tropical regions such as Sri Lanka. Understanding the multifaceted nature of heat vulnerability is crucial for devising effective adaptation strategies and mitigating the impacts of extreme heat events.

1.2.1. Conceptual Framework of Heat Vulnerability:

The concept of heat vulnerability encompasses a complex interplay of social, economic, environmental, and demographic factors that influence an individual or community's susceptibility to heat-related risks. Central to the conceptualization of heat vulnerability is the recognition of three key dimensions: exposure, sensitivity, and adaptive capacity (Kjellstrom et al., 2009). Exposure refers to the degree to which individuals or communities are subjected to heat stress, influenced by factors such as temperature, humidity, and urban heat islands. Sensitivity reflects the physiological and socio-economic characteristics that make certain groups more susceptible to heat-related health impacts, including age, pre-existing health conditions, and access to healthcare services. Adaptive capacity encompasses the ability of individuals, communities, and institutions to anticipate, prepare for, and respond to heatwaves, influenced by factors such as social support networks, infrastructure resilience, and governance structures.

1.2.2. Methodologies for Heat Vulnerability Assessment:

A variety of methodologies have been developed for assessing heat vulnerability, ranging from qualitative approaches to quantitative indices. Composite indices, such as the Environmental Vulnerability Index (EVI) and the Social Vulnerability Index (SVI), integrate multiple indicators to provide a comprehensive measure of vulnerability (Sachs et al., 2005; Cutter et al., 2003).

Geographic Information Systems (GIS) and spatial analysis techniques have also been widely utilized to map vulnerability patterns and identify hotspots of risk (Reid et al., 2009; Hondula et al., 2011). These methodologies enable researchers and policymakers to identify priority areas for intervention and allocate resources effectively.

1.2.3. Applications of HVIs in Different Contexts:

HVIs have been applied in diverse geographical contexts to assess vulnerability and inform adaptation strategies. Studies conducted in urban areas have highlighted the role of urban heat islands, socio-economic disparities, and land use patterns in shaping vulnerability patterns (Harlan et al., 2013). Regional studies, such as those focusing on coastal areas, have emphasized the importance of considering additional factors such as sea level rise and extreme weather events in vulnerability assessments (Turner et al., 2019). These studies underscore the need for context specific approaches to vulnerability assessment that account for local socio-economic, environmental, and climatic conditions.

1.2.4. Relevance of HVIs to Sri Lanka:

Sri Lanka's tropical climate and geographical location make it highly susceptible to heatwaves and related hazards. The country's socio-economic profile, including income inequality, population density, and access to healthcare, further exacerbates vulnerability to extreme heat events. Limited studies have explored heat vulnerability in the Sri Lankan context, highlighting the need for localized assessments and adaptation strategies tailored to the country's specific socio-economic and environmental conditions.

1.2.5. Challenges and Opportunities in HVI Development:

Despite the utility of HVIs in assessing vulnerability, challenges remain in data availability, quality, and spatial resolution, particularly in developing countries like Sri Lanka. Addressing these challenges requires collaboration between researchers, policymakers, and local communities to improve data collection and analysis methodologies. The development of an HVI specific to Sri

Lanka presents an opportunity to enhance understanding of heat vulnerability dynamics and inform targeted interventions to mitigate the impacts of heatwaves on public health, infrastructure, and livelihoods.

1.3 Research Gap

Inability to obtain information on heat wave resolution and the inability to obtain information simultaneously as a single point of location rather than Near the Location

Figure 1:

	Prediction Crops (Recommend)	Heat Wave Prediction	Support for Sri Lanka
1	✗	✓	✗
2	✗	✗	✗
3	✓	✓	✓
4	✗	✗	✗
Heatwave Map	✓	✓	✓

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In recent years, heatwave disruption has become a major worry for several industries, including agriculture. The suggested system focuses on various user groups that are affected by heatwaves in their daily lives. A valuable source for agricultural decision-making is the proposed heat resilience solutions combined with soil damage detecting technologies. It takes a lot of time and is inaccurate to use traditional procedures. More precise and current findings are obtained while training machine learning models. In terms of vast areas, this will be quite helpful. The answers for precise soil moisture predictions will come from this research. Any type of crop grown in an agricultural field may be impacted by soil damage caused by heatwaves.

The productivity will be immediately impacted by the degraded soil. Even those working in agriculture use sophisticated mobile devices these days. For those working in the agricultural sector, the mobile-based solution will therefore be simple to use and handy. Reduced awareness of the moisture content will result in lower crop productivity.

Using machine learning techniques to enhance soil moisture forecasts is part of the investigation into the connections between heatwaves and soil moisture. In this arena, several innovative machine learning-based solutions have been released. These systems employ a variety of data sources, including satellite images, to estimate soil moisture content with great spatial accuracy. For instance, a data-driven model has demonstrated the ability to estimate the moisture content of surface soil at an astounding spatial resolution of 50 meters by combining simulated data with optical, thermal, and radar imaging from satellites (1). A convolutional-regression model has also been created to combine passive and active microwave measurements from various satellites, allowing the extraction of volumetric soil moisture content in the top 5 cm of soil (2).

1.2 Background Literature

Heatwaves are become more severe through recent years in Sri Lanka and the impact of the Heatwaves also became more severe to the people. People started to face more higher temperature levels during these periods. Because of this vulnerabilities of heat related hazards became more critical and the there needs to be adaptation and risk mitigation methods to prevent from these hazards. Due to this natural hazard mitigate and effective adaptation is the best solution since we can not control this weather condition. Heatwaves have a direct impact to the soil moisture which directly affects to the productivity of the crops. This will be critical factor for the cultivators who located in frequent heatwave occurring areas.

1.2.1 Conceptual Framework of Soil moisture forecast

The concept of soil moisture involve understanding the complex dynamics of soil moisture levels, which are impacted by several environmental, geographical, and human factors, is essential to developing a conceptual framework for soil moisture forecasting. The approach, which was modified from Dirmeyer et al. (2013), identifies three basic components in the core which are drivers, indicators, and impacts. Drivers and indicators are the most effective parameters and drivers include topography, soil qualities, precipitation patterns, land cover/use, and climate variability, among other elements that affect soil moisture dynamics. In different geographical areas, the temporal and spatial distribution of soil moisture is influenced by the complex interactions among these causes.

The conceptual framework of soil moisture forecast places a strong emphasis on how natural processes, human activity, and socioeconomic variables are all interrelated in determining the dynamics of soil moisture. It offers a comprehensive knowledge of soil moisture variability and its consequences for the management of natural resources and the resilience of society by combining information from several disciplines, such as meteorology, hydrology, ecology, and agricultural science.

1.2.2 Methodologies for Soil moisture forecast

Different methods are developed for forecasting soil moisture levels, including both qualitative and quantitative methods, have been. Understanding soil moisture dynamics and determining susceptibility requires the use of composite indices and spatial analytic approaches.

The simulation of soil moisture dynamics based on inputs like precipitation, temperature, land use, and soil properties is made possible by hydrological models like the Variable Infiltration Capacity (VIC) model and the Soil and Water Assessment Tool (SWAT) (Neitsch et al., 2005; Liang et al., 1994).These are the traditional methods used over long period. These models help with proactive decision-making and risk mitigation activities connected to soil moisture variability by making it easier to forecast future soil moisture conditions under different situations.

Data from satellite and remote sensing technologies offering continuous, widely spaced measurements of land surface characteristics, satellite and remote sensing technologies are essential to the forecasting of soil moisture. Our comprehension of soil moisture variability is improved, and forecast generation is aided by these data sources, which provide insightful information on soil moisture dynamics at regional to global scales.

1.2.3 Applications of Soil moisture forecast in Different Context:

Soil moisture forecasting techniques are useful in different geographical contexts, providing information on the dynamics of soil moisture and helping to shape adaptation plans suited to particular environmental circumstances. Research which are done in agricultural areas has indicated how important it is to use soil moisture predictions to optimize crop selection, irrigation timing, and productivity (Mishra et al., 2012). Crop models and agronomic techniques may be integrated with predicted soil moisture data to help farmers optimize water management and reduce the effects of drought, and increase the productivity.

Soil moisture forecast is very important to managing water resources because they help determine streamflow, evaluate the severity of droughts, and control reservoir operations (Koster et al., 2009). Decisions on water distribution, flood prevention, and hydropower production are influenced by soil moisture forecasts, especially in areas where surface water availability and groundwater recharge are critical.

1.2.4 Relevance of Soil Moisture forecast to Sri Lanka :

The importance of soil moisture forecasting in Sri Lanka's environmental and socioeconomic context is highlighted by the geography, tropical climate, and seasonal rainfall patterns. Also the increase of the heatwave occurring is a considerable fact which the soil moisture forecasting is very useful for the cultivators. People are started to experience heatwaves more frequently during past few years.

Soil moisture availability is essential for crop production and livelihoods in agriculture, which is a major industry in Sri Lanka. For the purpose of maximizing planting schedules, irrigation management, and crop selection (particularly in areas vulnerable to drought or water scarcity) soil moisture predictions furnish farmers, agricultural policymakers with vital information (Jayantha and Somaratne, 2006). This information will reduce production risks, improve food security for rural populations, and implement climate-resilient agricultural practices by forecasting soil moisture levels.

1.2.5 Challenges and opportunities in Soil Moisture forecast:

Data Quality and Availability:

A major obstacle to soil moisture forecasting is obtaining high-quality and readily available input data, such as land cover, precipitation records, and soil parameters. Soil moisture estimates can be inaccurate in places like Sri Lanka due to low data coverage and restricted access to ground-based monitoring networks. Calibration and validation of the model are further complicated by inconsistent data gathering techniques and temporal gaps in historical records.

Using ground sensors is very complicated and impractical when it comes to cover the entire country. Also these sensor data can be unavailable or inaccurate due to the hardware failures.

1.3 Research Gap

	Prediction Crops (Recommend)	Heatwave Map	Heat Wave Prediction	Support for Sri Lanka
1	✕	✕	✓	✕
2	✕	✕	✕	✕
Our Application	✓	✓	✓	✓

2. RESEARCH PROBLEM

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Sri Lanka, a tropical island nation located in the Indian Ocean, is increasingly susceptible to the adverse impacts of heatwaves and extreme heat events due to the effects of climate change. However, despite the growing recognition of heat vulnerability as a pressing issue, there remains a significant gap in our understanding of the localized dynamics and determinants of vulnerability across different regions and communities within the country. The existing body of research on heat vulnerability in Sri Lanka is fragmented and often fails to provide a comprehensive assessment of the socio-economic, demographic, and environmental factors that contribute to vulnerability.

2. 1. Limited Understanding of Localized Heat Vulnerability Dynamics:

Current studies on heat vulnerability in Sri Lanka often employ broad-scale approaches or rely on global indices that may not capture the nuanced vulnerabilities present within specific geographic contexts. There is a lack of detailed insight into how vulnerability varies across urban and rural areas, coastal and inland regions, and different socio-economic strata. As a result, interventions and adaptation measures may not be effectively tailored to address the specific needs and vulnerabilities of different communities.

2.2. Inadequate Coverage of Socio-economic, Demographic, and Environmental Factors:

The existing literature on heat vulnerability in Sri Lanka predominantly focuses on meteorological variables such as temperature and humidity, overlooking the socio-economic, demographic, and environmental determinants of vulnerability. Factors such as poverty, inadequate housing, limited access to healthcare services, population density, and land use patterns are known to influence vulnerability but have not been comprehensively studied in the Sri Lankan context. Understanding the complex interactions between these factors is essential for developing targeted interventions to reduce vulnerability and enhance resilience.

2.3. Absence of a Standardized Heat Vulnerability Index (HVI) for Sri Lanka:

One of the critical challenges in assessing and addressing heat vulnerability in Sri Lanka is the absence of a standardized HVI tailored to the country's specific socio-economic, demographic, and climatic conditions. While global indices provide valuable insights into broad vulnerability trends, they may not adequately capture the unique vulnerabilities present within Sri Lanka. Developing a standardized HVI specific to Sri Lanka is essential for providing policymakers, planners, and public health authorities with actionable data to prioritize interventions and allocate resources effectively.

2.4. Implications for Public Health, Infrastructure, and Livelihoods:

The lack of comprehensive understanding and actionable data on heat vulnerability has significant implications for public health, infrastructure resilience, and livelihoods in Sri Lanka. Heatwaves pose significant risks to vulnerable populations, exacerbating pre-existing health conditions, straining healthcare systems, and increasing the incidence of heat-related illnesses and mortality. Critical infrastructure such as energy, water, and transportation systems are also vulnerable to heat stress, while agricultural productivity and livelihoods are threatened by heat-related impacts on crops and livestock.

2.5. Urgent Need for Evidence-based Adaptation Strategies and Policy Interventions:

Addressing the research problem outlined above is crucial for informing evidence-based adaptation strategies, policy interventions, and urban planning initiatives aimed at reducing the impacts of heatwaves and enhancing resilience in Sri Lanka. Developing a robust HVI framework specific to Sri Lanka will provide decision-makers with the necessary tools and insights to identify vulnerable communities, prioritize adaptation measures, and allocate resources effectively. By integrating localized data and stakeholder engagement, such an approach can contribute to building more resilient and sustainable communities in the face of escalating climate risks.

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Soil Moisture is an important variable that influences crop growth and yield, as well as the frequency and intensity of heatwaves, is soil moisture. However, soil moisture is also a complex and dynamic factor that is affected by a number of elements, including soil characteristics, weather, land use, and human activity. As a result, forecasting soil moisture that is precise and trustworthy is a difficult task that calls for advanced methods and data sources.

The following problem is the focus of the current study (proposed system):

2.1 Accurately predict the soil moisture under various climatic conditions.

Understanding the intricate relationships between weather patterns, soil characteristics, and plant dynamics is necessary to develop reliable soil moisture forecasts across a range of climatic situations. In order to take into consideration differences in temperature, humidity, precipitation, and evapotranspiration rates under various climatic regimes, this sub-research subject focuses on improving soil moisture prediction models. Researchers want to increase the accuracy and dependability of soil moisture forecasts by including soil properties and meteorological data into modeling frameworks. This would allow for more efficient use of water resources and agricultural planning in response to climatic unpredictability.

2.2 Integrating remote sensing data into soil moisture forecasting.

The dynamics of soil moisture over wide geographic areas and difficult terrain can be better understood with the use of remote sensing technology. The techniques for incorporating remote sensing data—such as satellite imaging and aerial sensors—into soil moisture forecasting models are investigated in this sub-research topic. The objective of research is to enhance the spatial and temporal resolution of soil moisture forecasts by creating methods and algorithms for obtaining pertinent soil moisture information from remote sensing data and incorporating it into hydrological models. Stakeholders may make well-informed decisions about agriculture, water management, and environmental preservation by using remote sensing data to obtain timely and spatially explicit soil moisture information.

2.3 Recommending suitable crops based on various climate conditions.

To maximize agricultural output and tolerance to climate fluctuation, crop selection must take local climatic circumstances into account. In order to suggest appropriate crop types based on current climate conditions, soil characteristics, and agronomic requirements, this sub-research subject focuses on creating decision support tools and algorithms. In order to provide farmers and other agricultural stakeholders with tailored advice, researchers plan to use crop suitability indices, soil moisture predictions, and climatic data. Stakeholders may improve food security in a variety of agricultural settings, maximize productivity potential, and reduce risks from climate extremes by providing customized crop suggestions.

3. RESEARCH OBJECTIVES

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3.1 Main Objective

The main objective of this research is to develop a comprehensive Heat Vulnerability Index (HVI) specifically tailored to the socio-economic, demographic, and environmental context of Sri Lanka, and to apply this index to assess heat vulnerability across different regions of the country.

Sri Lanka, like many other regions worldwide, faces increasing risks from heatwaves and extreme heat events due to climate change. Recognizing the urgent need to address these challenges, the main objective of this research is to develop a robust and locally relevant HVI that can serve as a key tool for understanding, assessing, and mitigating heat vulnerability in Sri Lanka.

The development of the HVI will involve a multi-faceted approach that integrates insights from existing literature, stakeholder consultations, and empirical data analysis. The index will be designed to capture the complex interplay of socio-economic, demographic, and environmental factors that contribute to heat vulnerability within the Sri Lankan context.

Key aspects of the HVI development process will include the identification and prioritization of relevant vulnerability indicators, the collection and compilation of appropriate data sources, and the formulation of a methodological framework for calculating the index. Special attention will be paid to ensuring the representativeness, reliability, and validity of the HVI across different geographic regions and population groups within Sri Lanka.

Once developed, the HVI will be applied to assess heat vulnerability across various administrative units and geographic regions of Sri Lanka. This will involve mapping spatial variations in vulnerability, identifying hotspots of vulnerability, and analyzing the underlying drivers of vulnerability within different communities.

Ultimately, the main objective of this research is not only to provide a comprehensive assessment of heat vulnerability in Sri Lanka but also to generate actionable insights that can inform evidence based decision-making and adaptation strategies. By enhancing our understanding of heat vulnerability dynamics and highlighting areas of priority for intervention, the HVI will contribute to building more resilient and sustainable communities in Sri Lanka in the face of escalating climate risks.

3.2 Specific Objectives

Identify and Prioritize Key Indicators: The first specific objective is to identify and The development of a comprehensive Heat Vulnerability Index (HVI) tailored to the socio-economic, demographic, and environmental context of Sri Lanka requires a systematic approach guided by specific objectives. These objectives outline the key steps involved in constructing the HVI framework, applying it to assess heat vulnerability across different regions of the country, and analyzing the underlying drivers of vulnerability. In this section, we provide a detailed overview of the specific objectives that will guide our research process and contribute to achieving our main goal of enhancing understanding and mitigating the impacts of heatwaves in Sri Lanka.

- **Identify and Prioritize Key Indicators**

  The first specific objective focuses on identifying and prioritizing key socio-economic, demographic, and environmental indicators that are relevant to assessing heat vulnerability in Sri Lanka. By conducting a comprehensive review of existing literature and consulting with stakeholders, we aim to identify indicators that capture the complex interplay of factors contributing to vulnerability within the Sri Lankan context. This objective lays the foundation for the subsequent steps in developing the HVI framework.

- **Collect and Compile Data Sources**

  The second objective is to collect and compile relevant data sources necessary for constructing the HVI framework. This involves gathering data on a wide range of variables, including socio-economic characteristics, demographic profiles, and environmental conditions, from diverse sources such as national surveys, census data, meteorological records, and satellite imagery. By compiling these data sources, we ensure the availability of comprehensive and representative datasets for calculating the HVI.

- **Develop Methodological Framework**

  The third objective focuses on developing a methodological framework for the calculation of the HVI. This involves determining appropriate weighting schemes for each indicator, selecting statistical techniques for normalization and aggregation, and establishing criteria for defining vulnerability thresholds. The methodological framework will be designed to ensure the reliability, validity, and robustness of the HVI across different regions and population groups within Sri Lanka.

- **Apply HVI to Assess Vulnerability**

  The fourth objective is to apply the developed HVI framework to assess heat vulnerability across different administrative units and geographic regions of Sri Lanka. This involves calculating HVI scores for each unit, mapping spatial variations in vulnerability, and identifying areas of high vulnerability or hotspots within the country. By applying the HVI, we aim to provide a comprehensive assessment of heat vulnerability dynamics in Sri Lanka.

- **Analyze Drivers of Vulnerability**

  The fifth objective is to analyze the drivers of heat vulnerability within Sri Lanka. This includes examining the relationships between HVI scores and various socio-economic, demographic, and environmental variables, such as poverty levels, population density, land use patterns, and access to infrastructure and services. The analysis will provide insights into the underlying factors contributing to vulnerability and inform targeted interventions.

- **Validate HVI**

  The sixth objective is to validate the HVI by comparing its results with observed heatrelated health outcomes, such as hospital admissions for heat-related illnesses. This validation process will assess the predictive validity and reliability of the HVI and ensure that it accurately reflects real-world vulnerability dynamics in Sri Lanka.

- **Disseminate Findings**

  The seventh objective is to disseminate the findings of the study to relevant stakeholders, including policymakers, urban planners, public health authorities, and community organizations. By effectively communicating the implications of the HVI findings, we aim to inform evidence-based decision-making and adaptation strategies in Sri Lanka.

- **Contribute to Climate Resilience**

  The final objective is to contribute to broader efforts to enhance climate resilience and adaptation in Sri Lanka. By generating actionable insights into heat vulnerability and highlighting areas of priority for intervention, the study aims to support the development of targeted adaptation measures, urban planning initiatives, and public health interventions that can build more resilient and sustainable communities in the face of escalating climate risks

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3.1 Main Objective

The main goal of this project is to create a complete system that uses an intuitive mobile application to monitor soil moisture levels in agricultural areas in real time. The system aims to provide growers with accurate and timely information to improve agricultural output by optimizing water management methods via the use of data integration and technological advancements. The following are the study's particular goals;

1.Create a User-Friendly Mobile Application for Real-Time Soil Moisture Monitoring: Cultivators may keep an eye on the soil moisture levels in their fields in real time by creating a mobile application that is easy to use.

2.Provide cultivators with simple-to-understand information on soil moisture and recommending suitable crops.

3.2 Specific Objective

To improve soil moisture forecasting skills, machine learning algorithms and satellite remote sensing data have become more effective tools. These technologies provide insightful information on soil moisture dynamics at different temporal and geographical scales. The particular goals specified for this component focused on optimizing the capabilities of these technologies to enhance the precision and dependability of soil moisture forecasts. The study attempts to identify essential characteristics and correlations for more accurate soil moisture forecasting by gathering and preprocessing satellite remote sensing data from many sensors and using sophisticated machine learning methods.

- **Identify and Prioritize Key Indicators**

Finding and ranking the most important indications that are pertinent to anticipating soil moisture is the primary goal of the first specific aim. The aim is to identify indicators that accurately reflect the intricate interactions among many elements affecting soil moisture dynamics in a particular region by means of a thorough examination of the body of current literature and active involvement with stakeholders. The basis for further steps in creating a strong soil moisture forecasting framework is laid by this approach. Soil type, vegetation density, land cover, precipitation patterns, and topographical features are a few examples of key indicators. Researchers can improve the accuracy of soil moisture forecasts and expedite data collecting by ranking these indicators.

- **Collect and Compile Data Sources**

The second goal is gathering and organizing pertinent data sources that are necessary to build an extensive framework for predicting soil moisture. This includes collecting information on a variety of factors, such as vegetation indices, land use/cover, soil properties, and climatic indicators. These datasets will be assembled from a variety of sources, including satellite images, weather station records, soil databases, and data from remote sensing. Researchers guarantee the availability of comprehensive and representative information required for precise soil moisture forecasting by compiling various data sources.

- **Develop Methodological Framework**

The third goal is to provide a systematic framework for predicting soil moisture. This framework comprises statistical approaches for data normalization and aggregation, criteria for setting soil moisture thresholds, and suitable weighting algorithms for each data source or indication. By using a methodological framework, soil moisture predictions should be reliable, resilient, and dependable at various temporal and geographical scales. Researchers can improve forecast accuracy and consistency by creating a consistent method for measuring soil moisture. This would help with managing water resources, agricultural management, and environmental conservation by enabling well-informed decision-making.

4. METHODOLOGY

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The development of a comprehensive Heat Vulnerability Index (HVI) for Sri Lanka requires a systematic approach that integrates data collection, indicator selection, index calculation, and validation procedures. In this section, we outline the methodology employed in this study to construct and apply the HVI framework, ensuring robustness, validity, and relevance to the socioeconomic, demographic, and environmental context of Sri Lanka.

4.1. Indicator Selection:

The first step in the methodology involves the selection of appropriate socio-economic, demographic, and environmental indicators to be included in the HVI framework. This process is guided by a comprehensive review of existing literature on heat vulnerability assessment methodologies, as well as consultations with relevant stakeholders, including government agencies, non-governmental organizations, and academic experts. Key indicators are identified based on their relevance to heat vulnerability and their availability within the Sri Lankan context.

4.2. Data Collection:

Once the indicators are identified, the next step is to collect relevant data from various sources, including national surveys, census data, meteorological records, remote sensing imagery, and administrative datasets. Data collection efforts are guided by the selected indicators and aim to capture a wide range of socio-economic, demographic, and environmental variables at both national and sub-national levels. Special attention is paid to ensuring the representativeness, reliability, and spatial coverage of the data sources.

4.3. Data Preprocessing:

Prior to index calculation, the collected data undergo preprocessing to address issues such as missing values, outliers, and inconsistencies. Data cleaning techniques, including imputation methods and outlier detection algorithms, are applied to ensure the integrity and quality of the dataset. Additionally, spatial data preprocessing techniques such as georeferencing, projection transformation, and spatial interpolation may be employed to standardize the spatial data layers and ensure compatibility with the chosen coordinate system.

4.4. Index Calculation:

The HVI is calculated using a composite index approach that aggregates individual indicators into a single vulnerability score. Various normalization techniques, such as z-score normalization or min-max scaling, may be applied to standardize the indicators and bring them to a common scale. Weighting schemes are then applied to the normalized indicators to reflect their relative importance in contributing to overall vulnerability. The weighted indicators are aggregated using an appropriate aggregation method, such as simple additive aggregation or weighted sum aggregation, to calculate the final HVI score for each administrative unit or geographic region.

4.5. Spatial Analysis:

Following index calculation, spatial analysis techniques are applied to map and visualize the spatial distribution of heat vulnerability across Sri Lanka. Geographic Information System (GIS) tools and software are utilized to create thematic maps depicting vulnerability hotspots, spatial patterns, and gradients across different regions of the country. Spatial statistics techniques, such as spatial autocorrelation analysis and hotspot identification, may be employed to identify statistically significant clusters of vulnerability and assess spatial relationships between vulnerability and other geographic factors.

4.6. Validation and Sensitivity Analysis:

The constructed HVI is validated through comparison with observed heat-related health outcomes, such as hospital admissions for heat-related illnesses, to assess its predictive validity and reliability. Sensitivity analysis is conducted to examine the robustness of the index to changes in indicator selection, weighting schemes, and aggregation methods. The sensitivity of the HVI to variations in input parameters is assessed to ensure the stability and consistency of the index results.

4.7. Interpretation and Reporting:

Finally, the results of the HVI analysis are interpreted and reported in a comprehensive manner, highlighting key findings, vulnerability trends, and policy implications. The spatially explicit nature of the index results allows for targeted interventions and adaptation strategies to be prioritized in areas with the highest levels of vulnerability. The findings of the study are disseminated to relevant stakeholders through reports, presentations, and other communication channels, aiming to inform evidence-based decision-making and adaptation planning in Sri Lanka.

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Soil moisture forecasting for various soil and climatic circumstances is accomplished using a four-step system that leverages machine learning algorithms and data from satellite remote sensing. First comes the collection and preparation of data from various sensors that may track parameters and soil moisture. The second stage involves drawing relevant characteristics and correlations for soil moisture forecasting from historical data using machine learning techniques like deep learning. In the third step, different types of data are compared and combined to improve the repeatability and accuracy of soil moisture estimate and prediction.

In order to enhance the machine learning models' functionality and utility for predicting soil moisture under various conditions, physical processes, hydrologic variables, and meteorological data are also added in the third stage. The fourth stage comprises assessing and improving the interpretability, uncertainty, and dependability of the machine learning models for soil moisture forecasting by methods such as feature significance analysis, sensitivity analysis, uncertainty quantification, or model validation.

4.1.Data Collection:

The purpose of this step is to collect data on soil moisture and related properties using a variety of sensors, such as thermal, radar, and optical ones. The ERA5-Land datasets, ASTER, MODIS, Sentinel-1, Sentinel-2, SMAP, and other sources are used. The goal of data collection is to include as many environmental factors as possible that are important for predicting and assessing soil moisture.

4.2.Data Preprocessing:

To guarantee consistency and suitability of gathered data for further analysis, data preparation techniques are used. To obtain uniform spatial resolution (e.g., 50m), temporal frequency (daily), and geographic scope, the data are resampled, clipped, filtered, combined, and flattened. Preprocessing seeks to harmonize the data and eliminate any anomalies or irregularities that might influence the results of the research.

4.3.Spactial Analysis:

In order to identify important features and connections from historical data, spatial analysis uses machine learning techniques like deep learning algorithms. Convolutional neural networks (CNNs), recurrent neural networks (RNNs), and graph convolutional networks (GCNs) are examples of machine learning models that are used to capture the temporal and spatial changes of soil moisture. To further improve the accuracy and dependability of soil moisture assessment and forecasting, data fusion techniques are also used to combine data from many satellite remote sensing sources.

4.4. Validation and Sensitivity Analysis:

Accuracy and dependability of machine learning models used for forecasting soil moisture must be evaluated through validation and sensitivity analysis. To assess the effectiveness of the model, metrics including reliability diagrams, coefficient of determination (R2), and mean squared error (MSE) are used. Analyses of interpretability, such as sensitivity and feature significance, aid in understanding how input features affect model predictions. In order to provide information on the resilience and dependability of a model, uncertainty analysis techniques such as uncertainty quantification and propagation compute confidence intervals or error limits for output predictions.

4.5.Interpretation and reporting:

At the last stage, the outcomes of the validation/sensitivity analysis and geographical analysis are interpreted and reported. Using the Python or R computer languages for data reporting and analysis, the results are presented in an easy-to-understand format. The reporting successfully conveys these insights to stakeholders and decision-makers, while the interpretation attempts to offer insights into soil moisture dynamics and prediction accuracy.

5. TESTING AND IMPLEMENTATIONS

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5.1 Testing

Once the Heat Vulnerability Index (HVI) framework has been developed, it is imperative to validate its performance and assess its reliability in capturing heat vulnerability dynamics within Sri Lanka. This testing phase plays a crucial role in ensuring the robustness and validity of the HVI, thereby enhancing its utility as a tool for informing evidence-based decision-making and adaptation strategies. In this section, we provide a detailed overview of the testing methodology employed in this study to validate and evaluate the HVI.

5.1.1. Rationale for Testing

The testing of the HVI serves multiple purposes, each contributing to the overall reliability and credibility of the index. Firstly, validation ensures that the HVI accurately reflects real-world vulnerability dynamics and effectively captures the socio-economic, demographic, and environmental factors influencing heat vulnerability in Sri Lanka. Secondly, testing helps to identify any limitations or biases inherent in the index construction process, allowing for refinement and improvement where necessary. Finally, validation provides stakeholders with confidence in the reliability and relevance of the HVI, facilitating its uptake and utilization in decision-making processes.

5.1.2. Key Components of Testing

The testing methodology encompasses several key components, each designed to rigorously assess the performance and reliability of the HVI:

- **Validation Data:** A dataset of observed heat-related health outcomes is collected from relevant sources, such as hospital records, health surveillance systems, and public health databases. This dataset serves as the basis for validating the HVI against real-world impacts of heatwaves on human health.

- **Comparison Analysis:** The constructed HVI scores for each administrative unit or geographic region are compared with the observed heat-related health outcomes to assess the predictive validity of the index. Statistical analysis techniques, such as correlation analysis, regression analysis, and hypothesis testing, are employed to examine the relationship between HVI scores and the frequency or severity of heat-related health events.

- **Spatial Analysis:** Spatial analysis techniques are utilized to assess the spatial concordance between HVI hotspots and observed clusters of heat-related health events. Geographic Information System (GIS) tools and software are employed to overlay HVI maps with maps of heat-related health outcomes, allowing for visual inspection of spatial patterns and correlations between vulnerability and health impacts.

- **Sensitivity Analysis:** Sensitivity analysis is conducted to examine the robustness of the HVI to variations in input parameters, including indicator selection, weighting schemes, and aggregation methods. By systematically varying these parameters and observing the resulting changes in HVI scores and spatial patterns of vulnerability, the stability and consistency of the index results can be assessed.

- **Cross-Validation:** Cross-validation techniques, such as leave-one-out cross-validation or k-fold cross-validation, may be employed to assess the generalizability of the HVI across different time periods or sub-samples of the dataset. By systematically withholding a portion of the validation data and recalculating the HVI using the remaining data, the accuracy and reliability of the index can be evaluated under different conditions and scenarios.

5.1.3. Reporting and Dissemination of Results

The results of the testing process are interpreted and reported in a comprehensive manner, highlighting the strengths, limitations, and implications of the HVI for heat vulnerability assessment in Sri Lanka. The findings are disseminated to relevant stakeholders through reports, presentations, and stakeholder engagement activities, aiming to inform evidence-based decisionmaking and adaptation planning efforts.

The findings from the testing phase of the Heat Vulnerability Index (HVI) are disseminated through comprehensive reports, policy briefs, and stakeholder engagement activities. These efforts aim to translate complex validation analysis into accessible insights, providing policymakers, practitioners, and community members with actionable information for addressing heat vulnerability in Sri Lanka. Through various channels such as workshops, seminars, and online platforms, the results are shared to foster collaboration, build capacity, and raise public awareness about the impacts of heatwaves and the importance of adaptation strategies. By engaging stakeholders and promoting knowledge exchange, the dissemination process ensures the long-term sustainability and utilization of the HVI as a valuable tool for enhancing resilience to climate change.

5.2 Implementations

Implementation Process

- **Stakeholder Engagement and Capacity Building**

The implementation of the HVI begins with stakeholder engagement and capacity-building activities aimed at ensuring buy-in and participation from relevant actors. Workshops, training sessions, and stakeholder consultations are conducted to familiarize policymakers, practitioners, researchers, and community members with the HVI methodology, data sources, and interpretation of results. These capacity-building efforts empower stakeholders to effectively utilize the HVI in decision-making processes and adaptation planning efforts.

- **Institutional Arrangements and Governance Structures**

Institutional arrangements and governance structures are established to support the implementation and institutionalization of the HVI within existing policy frameworks and decision-making processes. This may involve designating lead agencies or coordinating bodies responsible for overseeing the implementation of the HVI, establishing technical working groups or advisory committees to provide guidance and oversight, and integrating the HVI into relevant sectoral plans, policies, and strategies.

- **Data Collection and Compilation**

Data collection and compilation efforts are undertaken to gather the necessary socio-economic, demographic, and environmental data required for calculating the HVI. This involves accessing and synthesizing data from various sources, including national surveys, census data, administrative records, meteorological observations, satellite imagery, and spatial datasets. Quality assurance measures are implemented to ensure the accuracy, reliability, and consistency of the data collected.

- **Index Calculation and Mapping**

The calculated HVI scores are mapped and visualized using Geographic Information System (GIS) tools and software to provide a spatially explicit assessment of heat vulnerability across different regions of Sri Lanka. Thematic maps depicting vulnerability hotspots, spatial patterns, and gradients are generated to facilitate the identification of areas in need of targeted interventions and adaptation measures. These maps serve as valuable decision-support tools for policymakers, planners, and practitioners involved in climate change adaptation and resilience-building efforts.

- **Integration into Decision-Making Processes**

The HVI is integrated into decision-making processes at various levels, including national, regional, and local scales. HVI results are incorporated into sectoral plans, policies, and strategies to mainstream considerations of heat vulnerability into development agendas and investment priorities. Decision-makers utilize HVI insights to prioritize adaptation measures, allocate resources effectively, and develop targeted interventions aimed at reducing vulnerability and enhancing resilience to heatwaves.

- **Monitoring and Evaluation**

Mechanisms for monitoring and evaluating the implementation and impact of the HVI are established to track progress towards resilience-building goals and objectives. Indicators and metrics are developed to measure changes in vulnerability levels, adaptation outcomes, and the effectiveness of intervention measures over time. Regular assessments and reviews are conducted to identify successes, challenges, and areas for improvement, informing iterative refinements to the HVI methodology and implementation strategies.

- **Knowledge Sharing and Learning**

Knowledge sharing and learning platforms are created to facilitate exchange of experiences, best practices, and lessons learned among stakeholders engaged in HVI implementation. Communities of practice, online forums, and knowledge repositories are established to promote collaboration, innovation, and peer learning, enabling stakeholders to leverage collective expertise and resources in addressing common challenges related to heat vulnerability and climate resilience.

- **Community Engagement and Empowerment**

Community engagement and empowerment activities are conducted to ensure that vulnerable populations are actively involved in decision-making processes and adaptation efforts. Participatory approaches, community-based risk assessments, and local knowledge systems are integrated into HVI implementation to empower communities to identify their own vulnerabilities, prioritize adaptation needs, and co-design context-specific solutions that build resilience from the ground up.

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5.1 Testing

In order to make sure that our crop suggestion and soil moisture forecasting component are reliable and successful, testing is a crucial step. It is crucial to test the framework's performance and evaluate its dependability under many circumstances once it has been built for crop recommendations and soil moisture level predictions. In the end, this testing phase improves our model's usefulness as a tool for agricultural resilience decision-making by verifying the model's accuracy and resilience.

5.1.2. Key Components of Testing

1.Data validation:

Using input data sources such as satellite imaging, weather reports, and soil moisture measurements, we confirm the reliability and consistency of the information. In order to maximize accuracy and guarantee dependability, cross-referencing data from several sources is required.

2.Model validation:

We evaluate the efficacy of our machine learning models for crop recommendation and soil moisture forecasting. This entails using methods like cross-validation and validation against separate datasets to assess the generality, accuracy, and precision of the model.

3.Scenario Testing:

We test our system using scenarios to see how resilient it is to different farming scenarios and climates. To evaluate the resilience and flexibility of the system, this entails modeling various weather patterns, soil attributes, and agricultural management techniques.

3.Validation with ground truth:

We verify our model predictions with field observations and ground truth measures. In order to do this, actual data from soil moisture sensors and agricultural field surveys are compared with the expected amounts of soil moisture.

5.1.3. Reporting and Dissemination of Results

A key component of our predicting soil moisture and crop suggestion is reporting and sharing the results. Stakeholders, policymakers, and practitioners receive complete explanation and communication of the testing phase outcomes. In order to support evidence-based decision-making and adaptation planning efforts in agriculture, this approach attempts to illustrate the benefits, drawbacks, and effects of our model.

Comprehensive reports, policy briefings, and stakeholder engagement activities are some of the ways that the results from the testing phase of our crop recommendation and soil moisture forecasting system are shared. The aim of these attempts is to convert difficult validation analyses into comprehensible insights, offering practical knowledge for solving agricultural resilience in Sri Lanka.

5.2 Implementation

- **Data Collection and Compilation**

The process of gathering socio-economic, demographic, and environmental data necessary for crop selection and soil moisture forecasts is known as data collection and compilation. We learn and synthesize data from a number of sources, including administrative records, satellite imaging, national surveys, census data, and meteorological observations. In order to guarantee the precision, dependability, and consistency of the data gathered—and to provide a solid basis for more analysis—quality assurance procedures are put in place. Also we used satellite data for collecting soil moisture data for this research.

- **Index calculation and mapping**

With the use of Geographic Information System (GIS) hardware and software, the computed index for crop recommendation and soil moisture forecasts are plotted and displayed. Understanding vulnerability hotspots, geographical patterns, and grades across various agricultural regions is made possible by this spatially explicit evaluation. Policymakers, planners, and practitioners can use thematic maps as useful decision-support tools by using them to make it easier to identify locations that need specific interventions and adaptation measures.

- **Integrated with decision making**

Integration with Decision-Making procedures: From the national to the local levels, decision-making procedures include the crop recommendation and soil moisture forecasting indices. In order to mainstream agricultural risk into development agendas and targets for investment, these findings are integrated into sector plans, policies, and strategies. These findings are used by decision-makers to set priorities for adaptation strategies, distribute funds wisely, and create targeted actions that lessen vulnerability and increase resilience to changes in the climate.

- **Monitoring and evaluation**

Soil moisture forecasting indicators and crop recommendation systems are put in place with mechanisms for tracking and assessing their effectiveness. To track changes in adaption results, vulnerability levels, and the efficacy of intervention approaches over time, indicators and metrics are created. Iterative improvements to the approach and implementation methods are informed by regular assessments and reviews aimed at identifying areas of success, problems, and improvement.

- **Knowledge sharing and learning**

To promote the discussion of experiences, best practices, and lessons learned among stakeholders involved in crop recommendation and soil moisture forecasting, platforms for knowledge sharing and learning are developed. Building communities of practice, online forums, and knowledge repositories allows peer learning, innovation, and collaboration among stakeholders. This allows the stakeholders to combine their resources and expertise to address shared challenges related to climate resilience and agricultural vulnerability.

6. RESULTS & DISCUSSIONS

IT20145552 – Dissanayaka. D. M. S. M

6.1 Results

The Heatwave Map provides a spatially explicit representation of heat vulnerability across Sri Lanka, highlighting areas of elevated risk and susceptibility to extreme heat events. Using Geographic Information System (GIS) tools and software, the Heatwave Map integrates various socio-economic, demographic, and environmental indicators to generate a comprehensive assessment of vulnerability at both national and sub-national levels.

- **Spatial Patterns of Vulnerability:** The Heatwave Map reveals distinct spatial patterns of vulnerability, with certain regions exhibiting higher levels of susceptibility to heatwaves compared to others. Coastal areas, urban centers, and low-lying regions are identified as hotspots of vulnerability, characterized by dense populations, inadequate infrastructure, and limited access to adaptive resources. In contrast, mountainous and forested areas tend to have lower vulnerability, attributed to cooler temperatures, higher elevation, and greater ecological resilience.

- **Identification of Hotspots:** Hotspots of vulnerability are identified on the Heatwave Map, indicating areas with the highest concentration of risk factors and the greatest potential for adverse impacts from heatwaves. These hotspots serve as focal points for targeted interventions and adaptation measures, directing resources towards the most vulnerable communities and regions. By prioritizing action in hotspots, policymakers and practitioners can effectively reduce vulnerability and enhance resilience to heatwaves in Sri Lanka.

- **Temporal Dynamics and Seasonal Variability:** The Heatwave Map also captures temporal dynamics and seasonal variability in vulnerability, reflecting changes in climatic conditions, population dynamics, and socio-economic factors over time. Seasonal variations in vulnerability are observed, with vulnerability levels fluctuating in response to seasonal changes in temperature, precipitation, and humidity. Understanding these temporal dynamics is crucial for developing adaptive strategies that account for seasonal variability and anticipate future climate impacts.

- **Utility for Decision-Making:** The Heatwave Map serves as a valuable decision-support tool for policymakers, planners, and practitioners involved in climate change adaptation and resilience-building efforts. By providing a visual representation of vulnerability patterns and hotspots, the Heatwave Map facilitates informed decision-making, resource allocation, and intervention planning. Stakeholders can utilize the map to prioritize adaptation measures, target investments, and develop localized strategies tailored to the specific needs of vulnerable communities and regions.

- **Limitations and Future Directions:** While the Heatwave Map offers valuable insights into heat vulnerability in Sri Lanka, it is important to acknowledge its limitations and areas for further refinement. Data gaps, uncertainties, and methodological limitations may impact the accuracy and reliability of the map, warranting continued efforts to improve data quality, enhance modeling techniques, and incorporate stakeholder feedback. Future research directions may include the integration of additional indicators, refinement of vulnerability modeling techniques, and validation against observed heat-related health outcomes to enhance the robustness and utility of the Heatwave Map.

6.2 Research Findings

- **Spatial Distribution of Vulnerability:**

  The research findings reveal a heterogeneous spatial distribution of vulnerability to heatwaves across Sri Lanka. Coastal areas and urban centers are identified as hotspots of vulnerability, characterized by high population density, inadequate infrastructure, and limited access to adaptive resources. In contrast, inland and mountainous regions exhibit lower vulnerability, attributed to cooler temperatures, higher elevation, and greater ecological resilience.

- **Key Drivers of Vulnerability:**

  Socio-economic, demographic, and environmental factors emerge as key drivers of vulnerability to heatwaves in Sri Lanka. Factors such as poverty, inadequate housing, lack of access to healthcare, and exposure to extreme heat exacerbate vulnerability among marginalized communities, including informal settlements and rural areas. Population density, land use patterns, and proximity to water bodies also influence vulnerability levels, with densely populated urban areas and coastal settlements facing heightened risks.

- **Temporal Dynamics and Seasonal Variability:**

  The research findings highlight temporal dynamics and seasonal variability in vulnerability, with vulnerability levels fluctuating in response to seasonal changes in temperature, precipitation, and humidity. Vulnerability tends to peak during the dry season when temperatures are highest and access to water and cooling resources is limited. Understanding these temporal dynamics is essential for developing adaptive strategies that account for seasonal variability and anticipate future climate impacts.

- **Implications for Adaptation and Resilience-building:**

  The research findings have significant implications for climate change adaptation and resilience-building efforts in Sri Lanka. By identifying vulnerable areas and populations, policymakers, planners, and practitioners can prioritize adaptation measures, target investments, and develop localized strategies tailored to the specific needs of vulnerable communities and regions. Interventions such as improved urban planning, enhanced healthcare infrastructure, and community-based early warning systems can help mitigate the impacts of heatwaves and enhance resilience to climate change.

- **Role of the Heat Vulnerability Index (HVI):**

  The research findings underscore the importance of the Heat Vulnerability Index (HVI) as a valuable tool for assessing and addressing heat vulnerability in Sri Lanka. The HVI provides a comprehensive and spatially explicit assessment of vulnerability, integrating socio-economic, demographic, and environmental indicators to identify areas of high vulnerability and prioritize adaptation measures. By integrating HVI insights into decision-making processes and policy frameworks, stakeholders can effectively reduce vulnerability and build resilience to heatwaves and climate change impacts.

6.3 Discussion

6.3.1. Normal Behavior

Normal behavior on the heat vulnerability map refers to patterns of vulnerability that align with expectations based on socio-economic, demographic, and environmental factors. In Sri Lanka, normal vulnerability patterns may include higher vulnerability in densely populated urban areas, coastal regions, and areas with limited access to healthcare and adaptive resources. These areas may experience elevated risks during heatwaves due to factors such as high population density, inadequate infrastructure, and exposure to extreme heat. Additionally, vulnerability may vary seasonally, with vulnerability levels peaking during the dry season when temperatures are highest and access to water and cooling resources is limited. Understanding and mapping these normal vulnerability patterns provide valuable insights for adaptation planning and resource allocation under typical climate conditions.

6.3.2. Abnormal Behavior

Abnormal behavior on the heat vulnerability map refers to patterns of vulnerability that deviate significantly from the expected norms or exhibit unusual characteristics. This could include sudden spikes or clusters of vulnerability in areas not typically considered vulnerable, as well as unexpected changes in vulnerability levels over time. For example, abnormal vulnerability patterns may emerge in response to extreme weather events, rapid urbanization, or socio-economic disruptions that disrupt normal socio-economic and environmental conditions. Identifying abnormal vulnerability patterns can serve as an early warning sign of emerging risks and vulnerabilities, prompting the need for targeted interventions and adaptive measures to address the underlying drivers of vulnerability and build resilience to future climate impacts. Additionally, abnormal vulnerability patterns may highlight areas where existing adaptation strategies and policies are inadequate or ineffective, signaling the need for policy reform and institutional strengthening to better address evolving climate risks

Figure 2:

ABNORMAL BEHAVIOR

Spotting Oddities

- Look for areas that stand out with unusually high or low vulnerability levels.

Using Numbers

- Use simple calculations to see if vulnerability levels are significantly different from the average.

Looking Over Time

- Check if vulnerability levels suddenly change over time without a clear reason.

Comparing Places

- Compare vulnerability in different areas to spot any disparities or inconsistencies.

Asking People

- Talk to locals or experts to confirm if vulnerability levels seem unusual in certain areas.

Taking A ction

- Develop specific plans to address abnormal vulnerability in areas that stand out.

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6.1.Results

Understanding the agricultural resilience and vulnerability in Sri Lanka is made possible by the Crop Recommendation and Soil Moisture Forecasting component. Thanks to the application of sophisticated modeling methods and GIS analysis, the findings provide a thorough grasp of crop adaptability and soil moisture dynamics in response to changing climate conditions.

- **Temporal Dynamics and Seasonal Variability**

Seasonal Changes and Temporal Dynamics: This component represents changes in crop adaptability and meteorological conditions throughout time, as well as seasonal variations in soil moisture levels. There are seasonal differences in agricultural productivity and soil moisture availability, which highlights the significance of adaptive techniques that take seasonal variability into account and predict future conditions for growth of crops.

- **Utility for Decision making**

Planners and other agricultural stakeholders can benefit greatly from the results of the crop recommendation and soil moisture forecasting component. The results support well-informed decision-making, resource allocation, and adaptation planning by offering practical insights into soil moisture dynamics and crop adaptability. With the use of this data, stakeholders may improve irrigation techniques, prioritize crop choices, and create specialized plans to increase agricultural resilience to climate change.

- **Limitation and Future Direction**

It is important to recognize the component's limitations and potential areas for development even if it provides insightful information about agricultural resilience and vulnerability. The reliability and accuracy of the results might be impacted by missing data, doubts about modeling methods, and difficulties with validation. To improve the accuracy and usefulness of the crop recommendation and soil moisture forecasting component, future research activities might involve honing modeling techniques, adding more indicators, and validating results against actual agricultural outcomes. In order to advance the component's benefit and application in increasing agricultural resilience in Sri Lanka, it will be imperative to continue efforts to improve data quality, refine modeling approaches, and involve stakeholders.

6.2.Research Findings

1.Geographical Distribution of Agricultural Vulnerability: The results of the research show that there are many different geographic distributions of vulnerability in Sri Lanka's agriculture industry. Certain places, such as coastal low-lying areas and areas with significant agricultural activity, may be more vulnerable to crop stress and variations in soil moisture. On the other hand, because to many characteristics including soil type, geography, and land use practices, highland areas or regions with a variety of cropping patterns may show reduced susceptibility.

2. Importance for Adaptation in Agriculture and Establishing Resilience: Significant effects flow from the research findings for Sri Lanka's attempts to create resilience and adapt agriculture. Agricultural extension staff, farmers, and politicians may identify vulnerable people and agricultural regions and then prioritize adaptation measures including improving water management techniques, investing in agricultural infrastructure, and encouraging cropping systems that are adaptable to climate change. To improve agricultural resilience and livelihood security in the face of climate change impacts, context-specific adaptation techniques should be put into practice.

3. Role of Soil Moisture Forecasting and Crop Recommendation Tools: The findings of the research show how crucial it is for agricultural decision-makers to use cutting-edge instruments and technology for predicting soil moisture and recommending crops. Crop compatibility evaluations and real-time soil moisture predictions may be integrated into agricultural planning and management techniques to improve sustainable agricultural growth and increase farmers' adaptive capability. Through the use of data-driven methodologies and participatory decision-making procedures, stakeholders in Sri Lanka's agricultural sector may successfully mitigate agricultural vulnerability and enhance resilience to climate change.

6.3.Discussion

Normal Behavior: Expected patterns of soil moisture levels and crop suitability based on historical data, agronomic practices, and climatic variables are referred to as normal behavior in the context of crop recommendation and soil moisture forecasting. For instance, some crops could be more suitable and productive in areas with enough soil moisture and ideal weather, whereas other crops would do better in well-drained soils with moderate moisture content. In contrast, agricultural regions that have access to dependable irrigation infrastructure and a variety of farming strategies may be less vulnerable to extreme weather events and changes in soil moisture. In order to maximize crop selection, irrigation control, and agricultural practices to improve production and resilience under typical climatic conditions, it can be very helpful to understand and map these regular behavior patterns.

Abnormal Behavior: In the context of crop recommendation and soil moisture forecasting, abnormal behavior is defined as departures from typical patterns or unexpected changes in crop suitability and soil moisture levels that might point to new hazards or vulnerabilities. This might include sudden changes in soil moisture levels brought on by severe weather, land degradation, or modifications to land use techniques that interfere with regular farming activities. Unexpected changes in crop performance or appropriateness in response to shifting climatic circumstances, pest and disease outbreaks, or socioeconomic changes can also be signs of abnormal behavior. Unusual behavior patterns can be used as an early warning system for future crop failures, yield losses, or agricultural disasters. This can lead to the implementation of preventative measures like crop diversification, timely irrigation interventions, or disaster risk management plans.

7. RESEARCH OUTPUT

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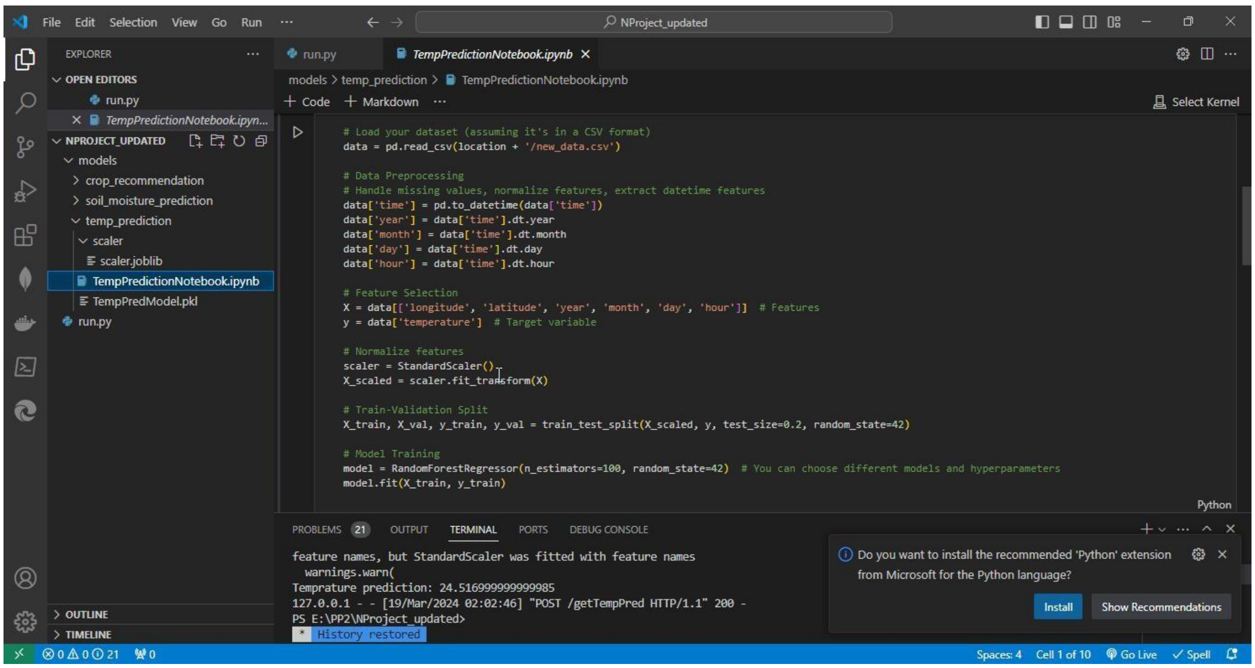
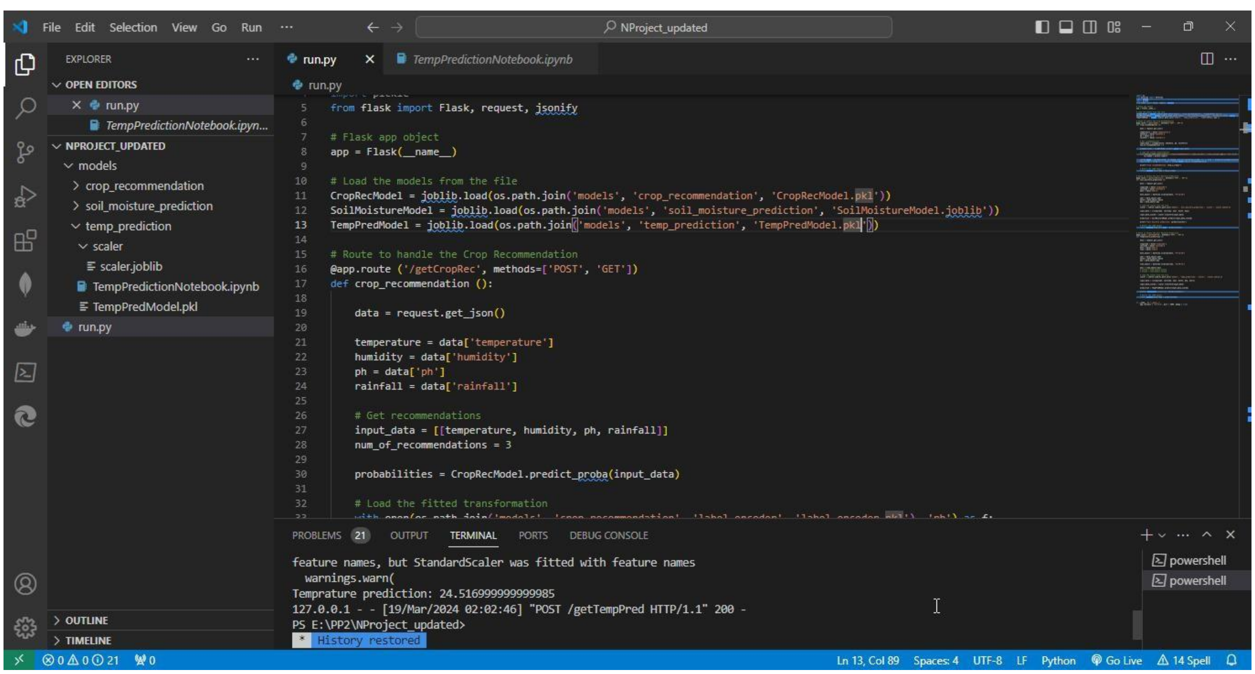
7.1 Code

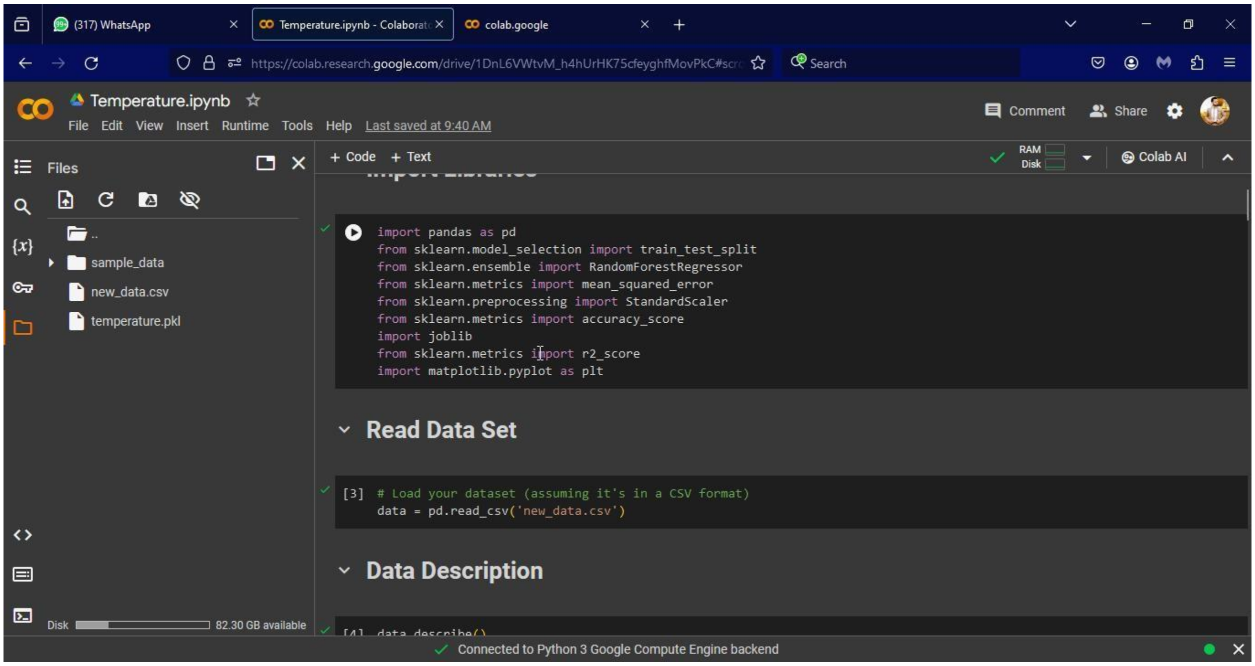
Figure 3:





7.2 Model Running

Figure 4:



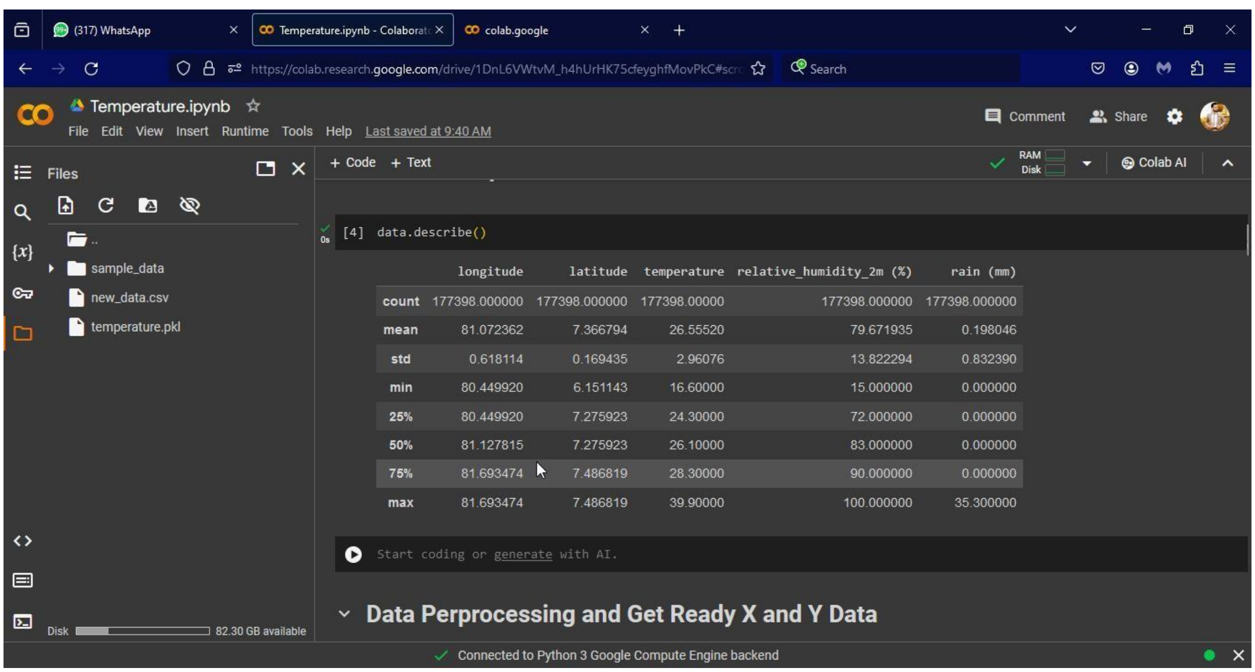
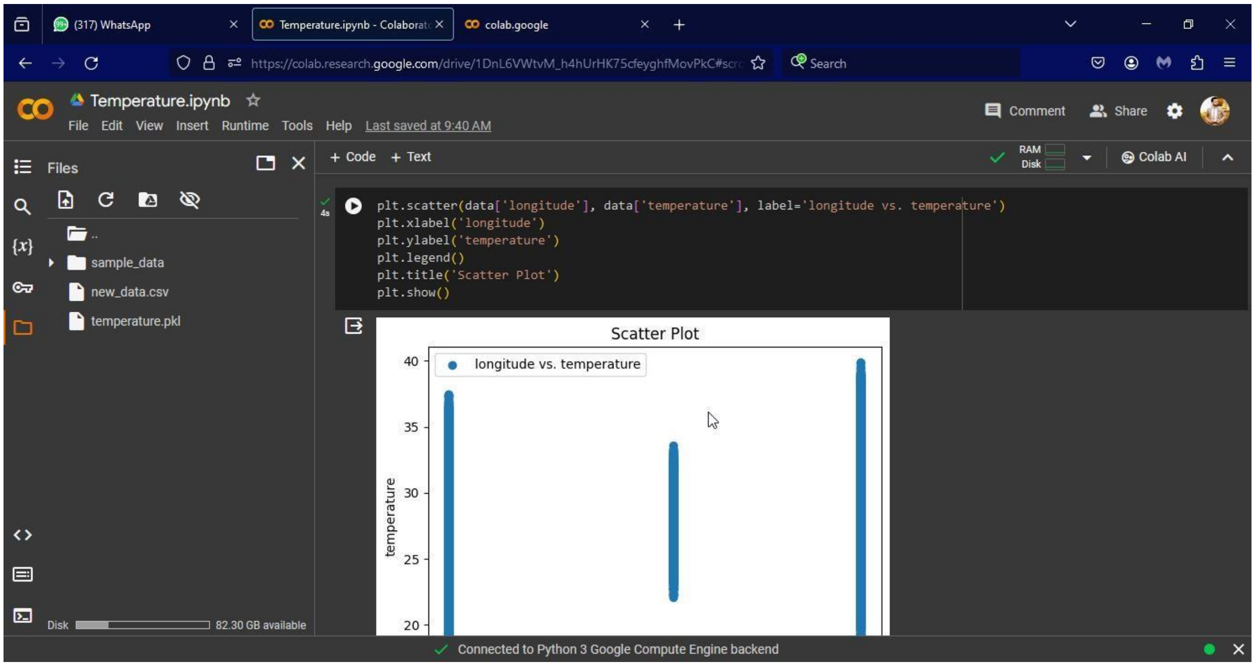


Figure 5: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colab.google
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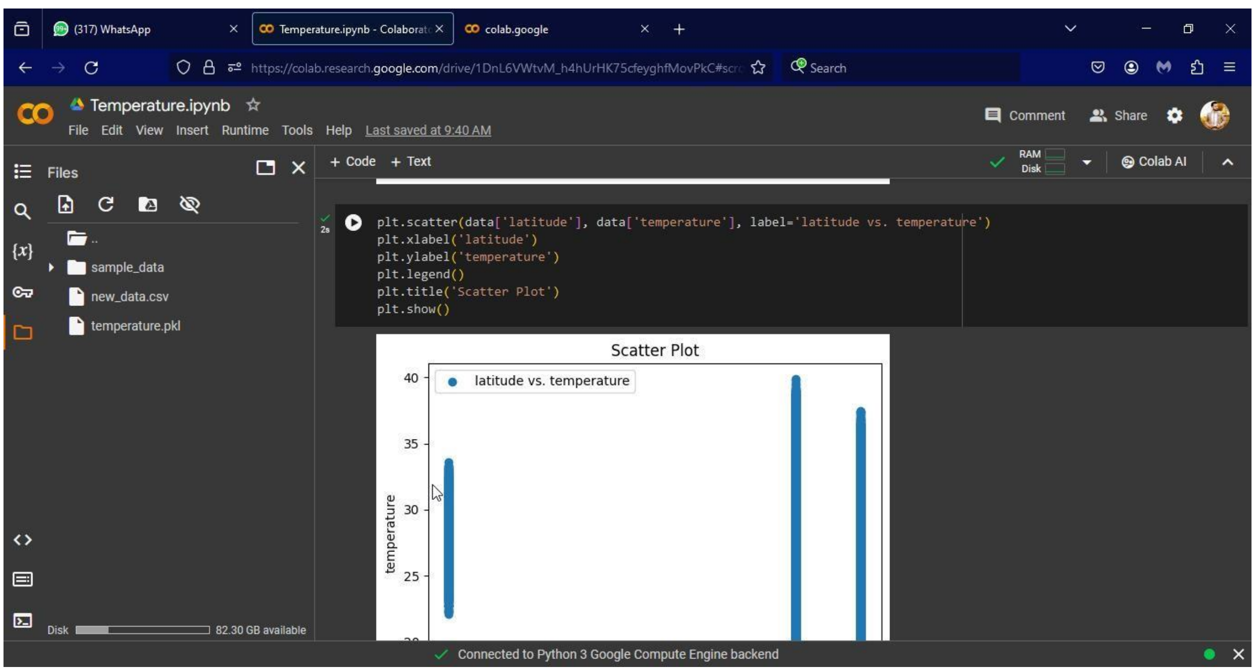
Search
Temperature.ipynb
File Edit View Insert Runtime Tools Help Last saved at 9:40 AM
Comment
Share
+ Code + Text
RAM
Disk
Colab AI
Files
sample_data
new_data.csv
temperature.pkl
plt.scatter(data['longitude'], data['temperature'], label='longitude vs. temperature')
plt.xlabel('longitude')
plt.ylabel('temperature')
plt.legend()
plt.title('Scatter Plot')
plt.show()
Scatter Plot
longitude vs. temperature
temperature
40
35
30
25
20
Disk 82.30 GB available
Connected to Python 3 Google Compute Engine backend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Temperature.ipynb - Colaborat
colab.google
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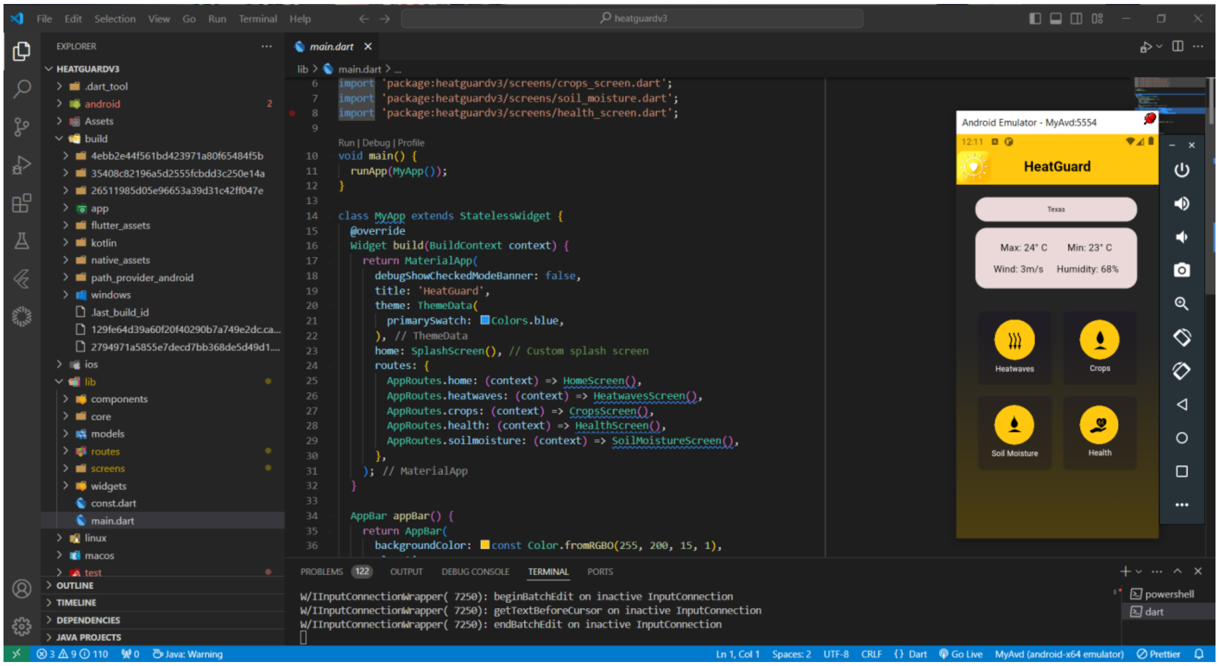
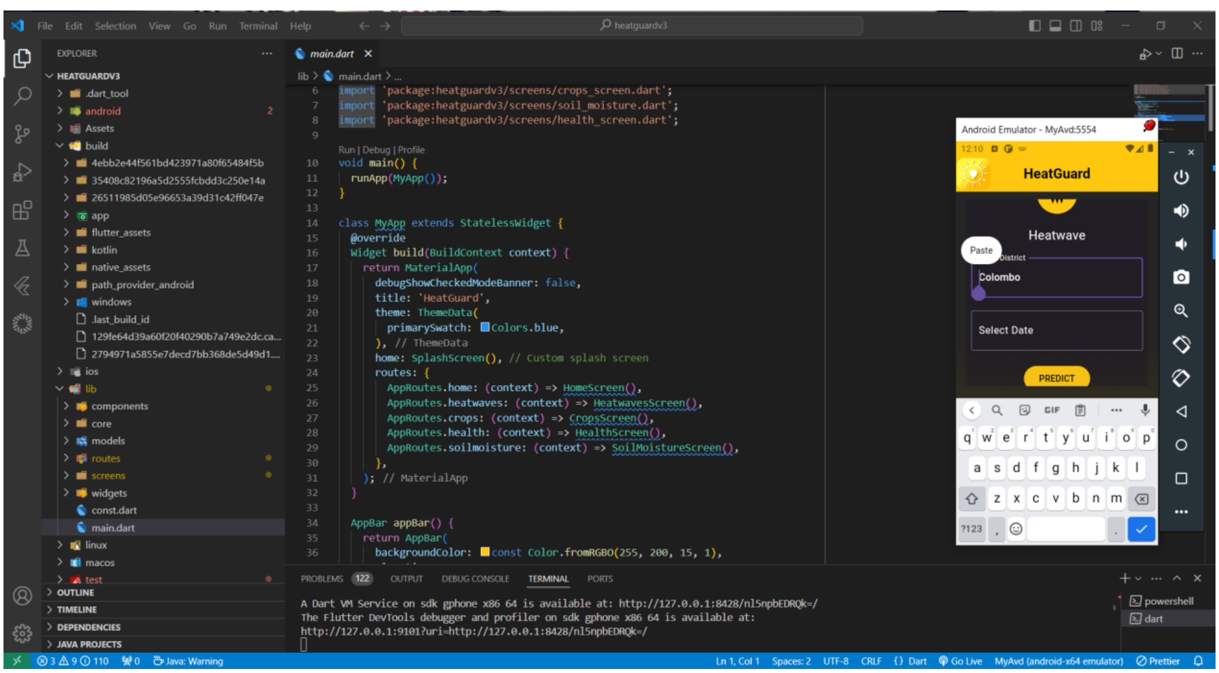
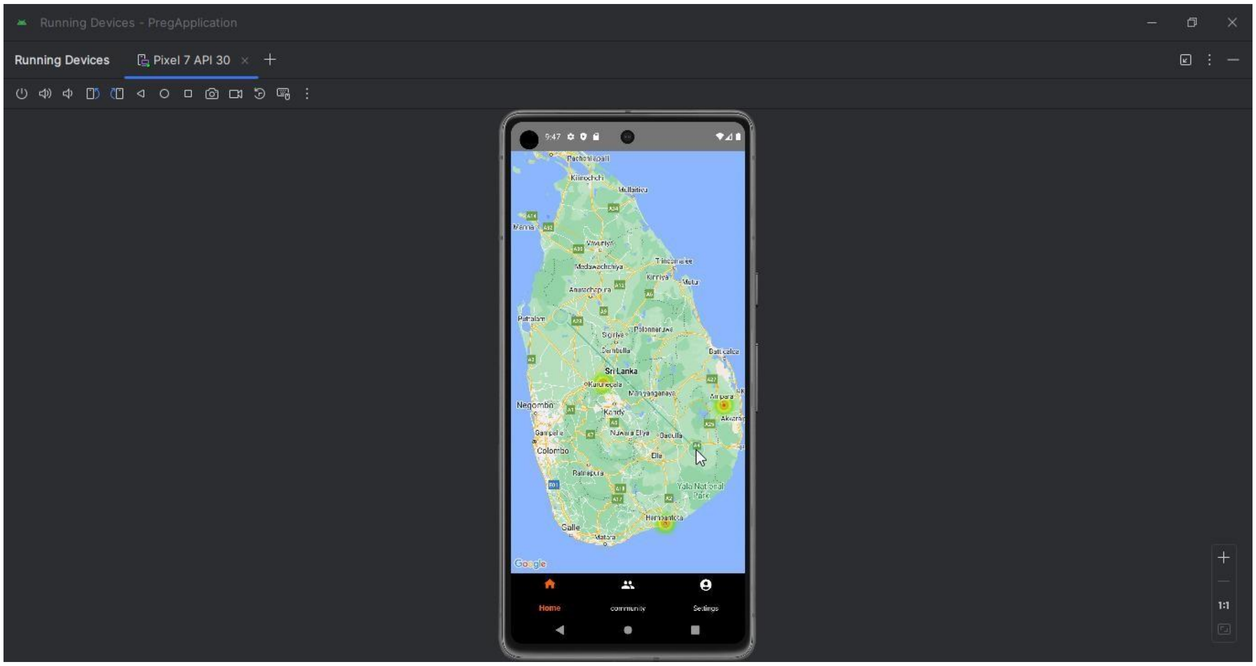
Search
Temperature.ipynb
File Edit View Insert Runtime Tools Help Last saved at 9:40 AM
Comment
Share
+ Code + Text
RAM
Disk
Colab AI
Files
sample_data
new_data.csv
temperature.pkl
plt.scatter(data['latitude'], data['temperature'], label='latitude vs. temperature')
plt.xlabel('latitude')
plt.ylabel('temperature')
plt.legend()
plt.title('Scatter Plot')
plt.show()
Scatter Plot
latitude vs. temperature
temperature
40
35
30
25
Disk 82.30 GB available
Connected to Python 3 Google Compute Engine backend

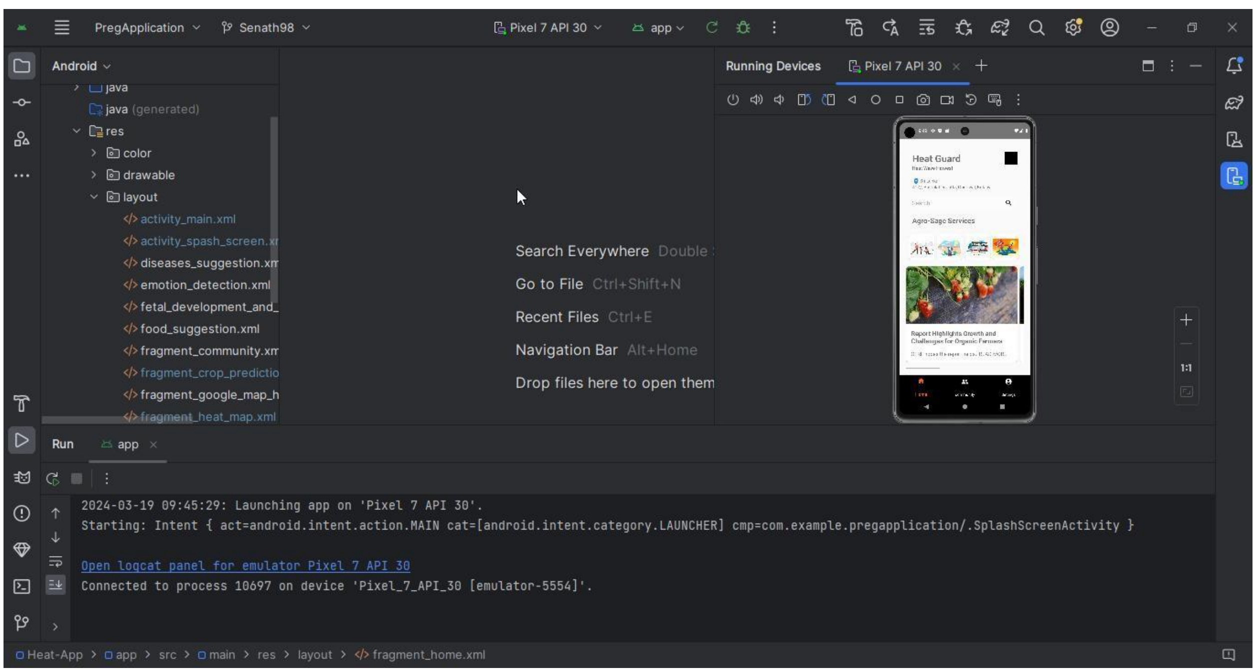
7.3. User Interface

Figure 6:



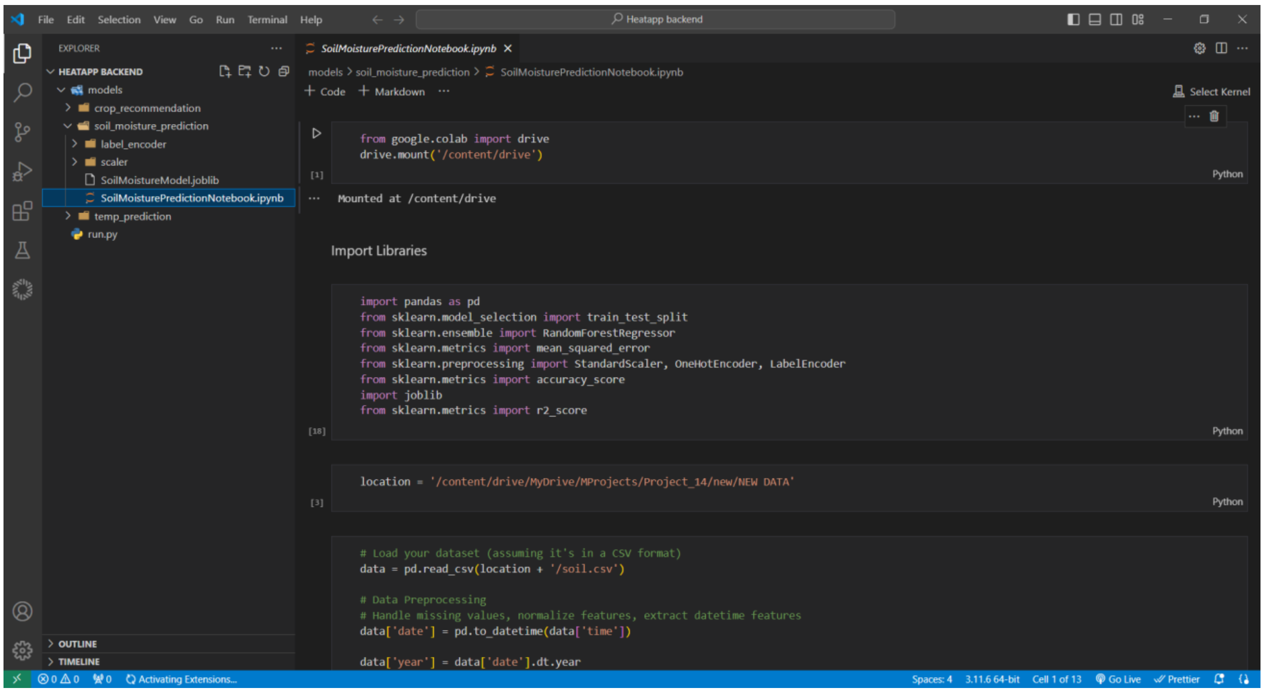


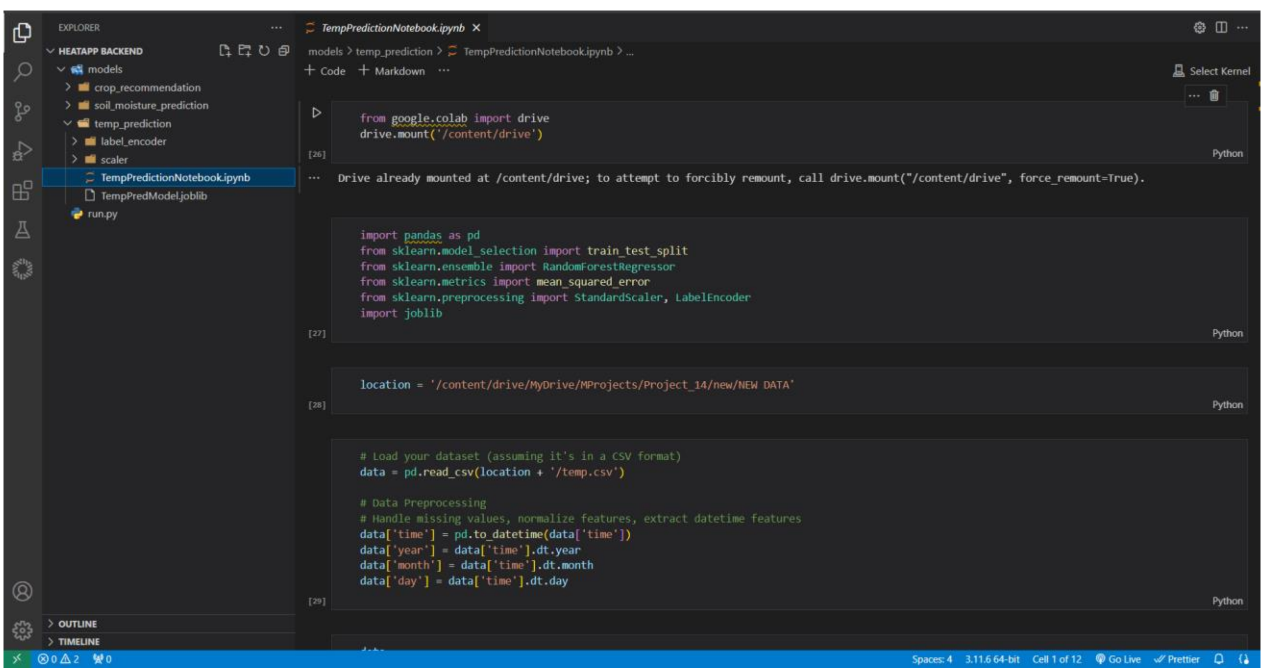

Running Devices - PregApplication
Running Devices
Pixel 7 API 30
Sri Lanka
Negombo
Colombo
Kandy
Galle
Home
community
Settings


PregApplication
Senath98
Pixel 7 API 30
app
Android
java
java (generated)
res
color
drawable
layout
activity_main.xml
diseases_suggestion.xm
emotion_detection.xml
food_suggestion.xml
fragment_community.xm
fragment_google_map_h
fragment_heat_map.xml
Search Everywhere Double
Go to File Ctrl+Shift+N
Recent Files Ctrl+E
Navigation Bar Alt+Home
Drop files here to open them
Running Devices
Pixel 7 API 30
Heat Guard
Agro-Sage Services
Run
app
2024-03-19 09:45:29: Launching app on 'Pixel 7 API 30'.
Starting: Intent { act=android.intent.action.MAIN cat=[android.intent.category.LAUNCHER] cmp=com.example.pregapplication/.SplashScreenActivity }
Open logcat panel for emulator Pixel 7 API 30
Connected to process 10697 on device 'Pixel_7_API_30 [emulator-5554]'.
Heat-App > app > src > main > res > layout > fragment_home.xml

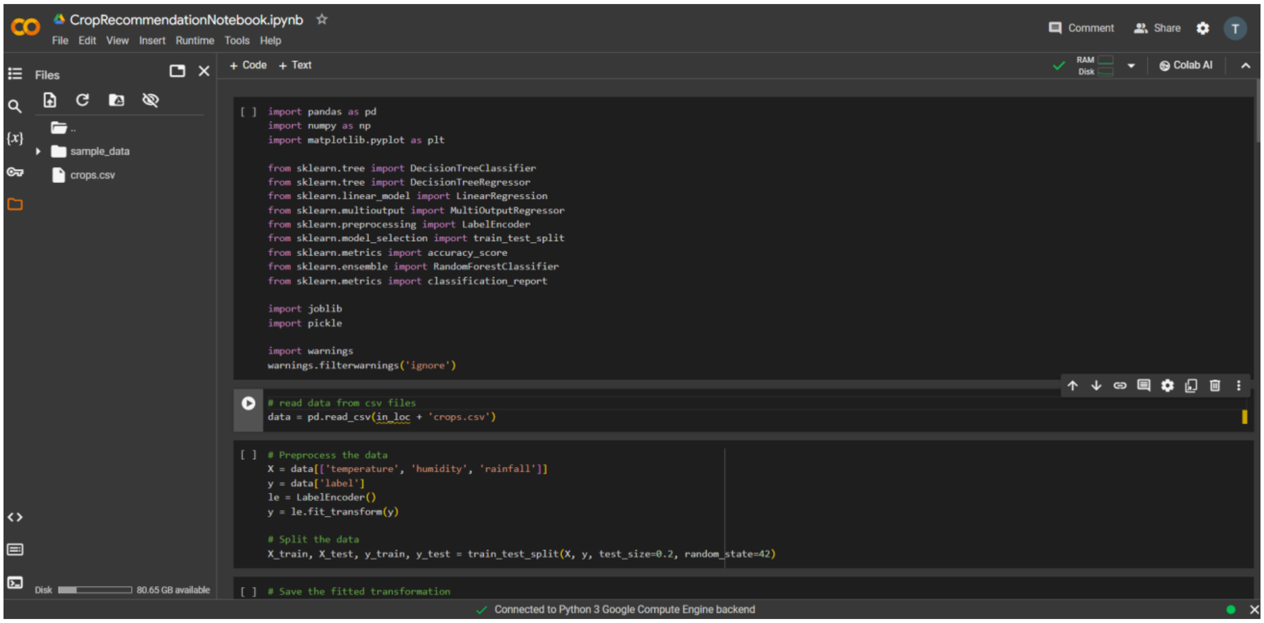
IT20142728 – Ranawaka. T. D

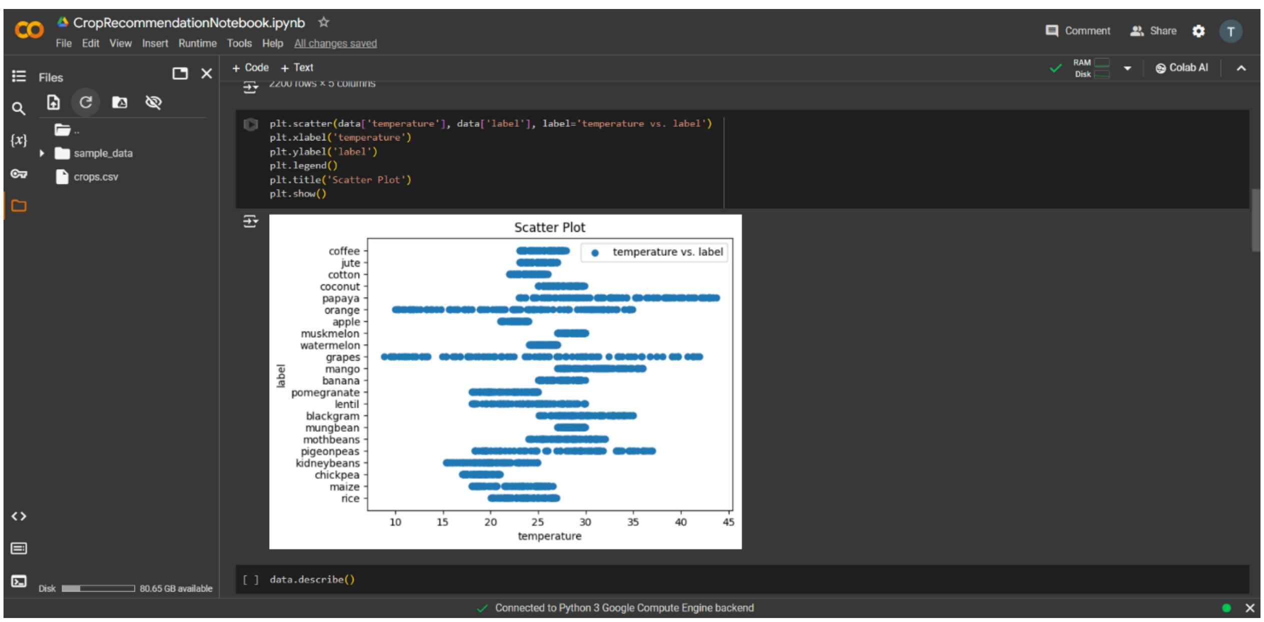
7.1.Code

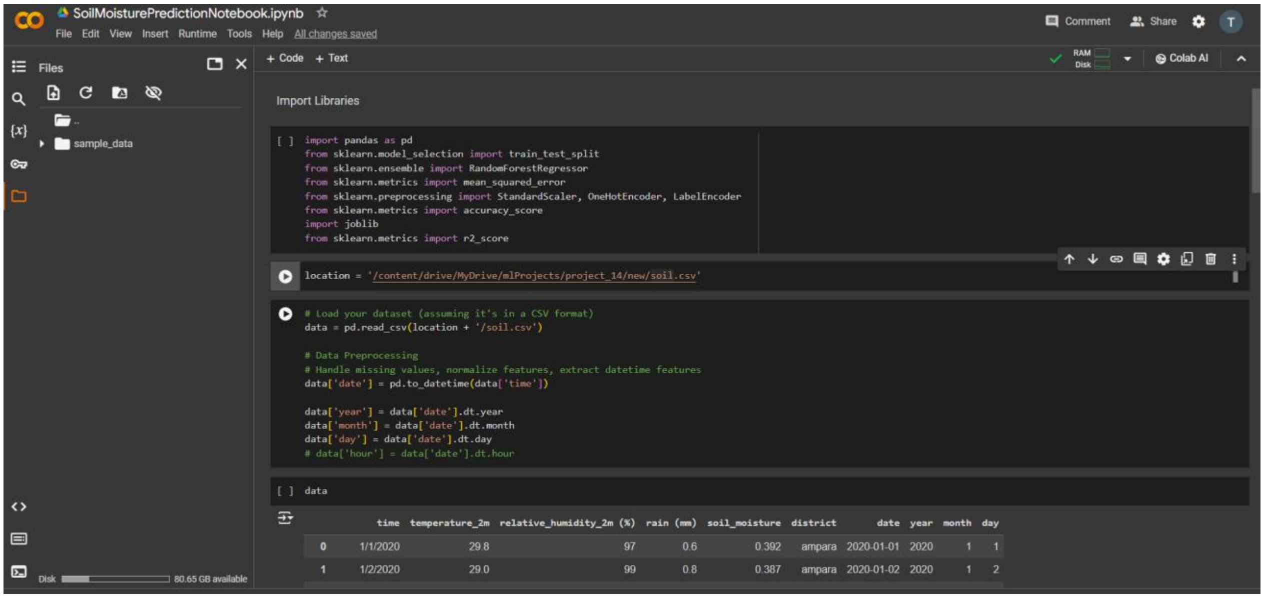


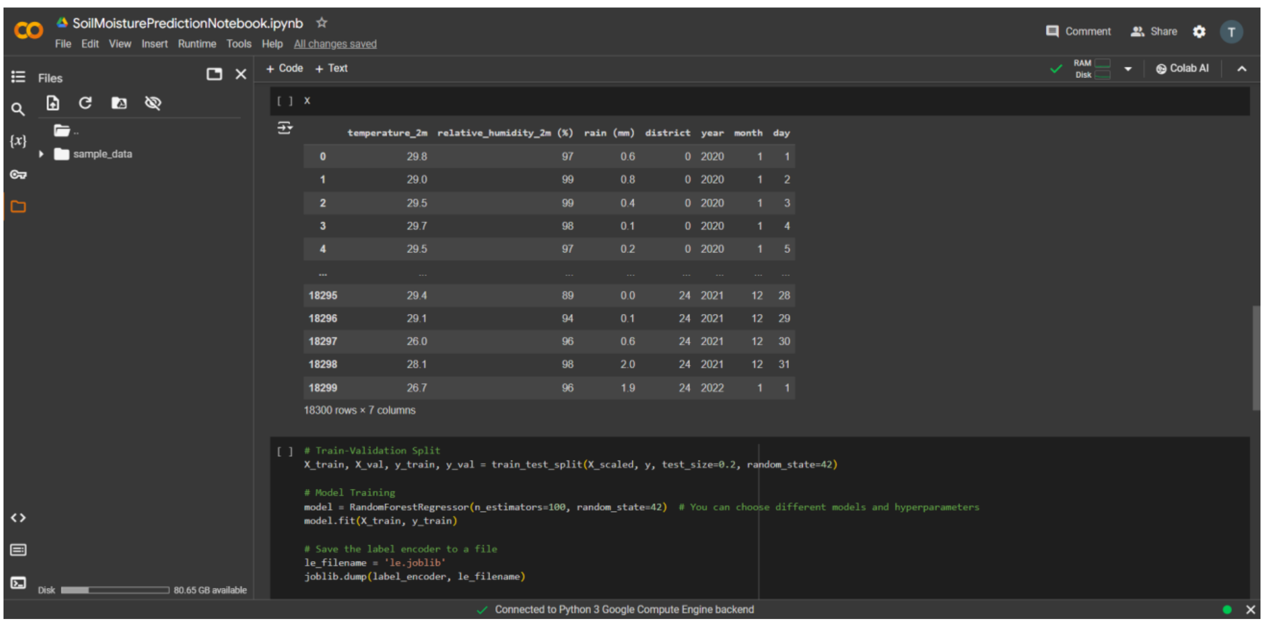


7.2.Model

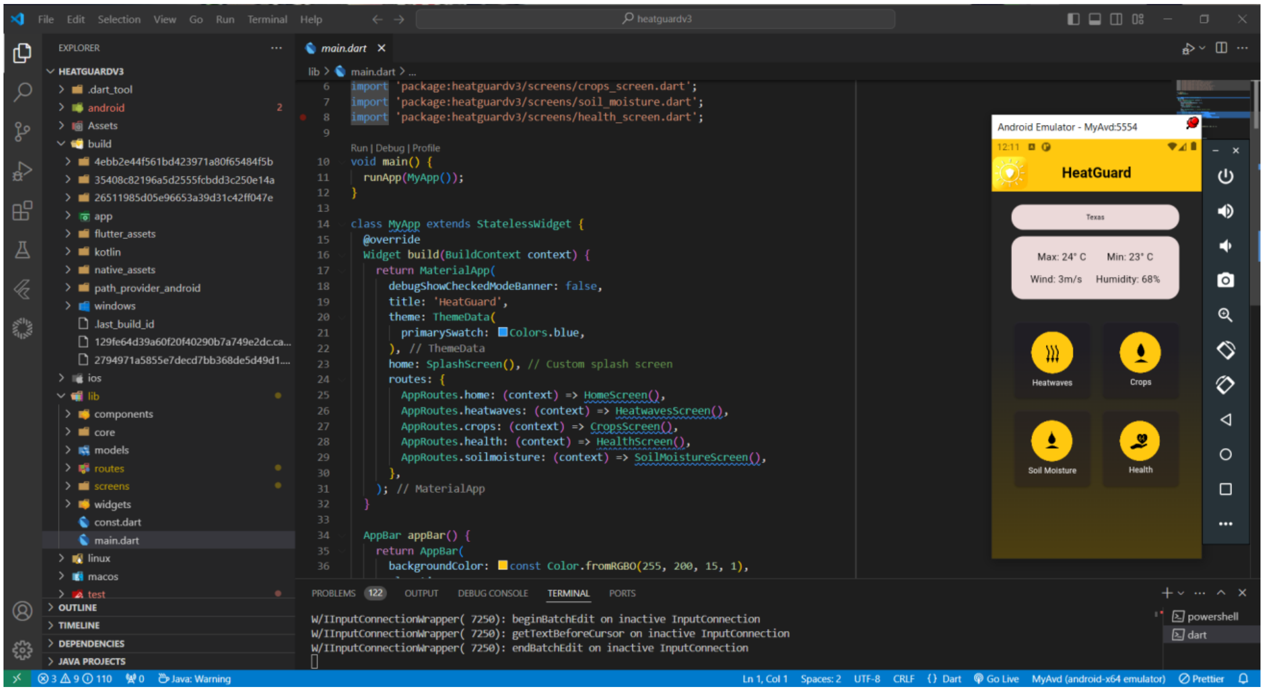

CropRecommendationNotebook.ipynb
File Edit View Insert Runtime Tools Help
Comment Share
Files
sample_data
crops.csv
+ Code + Text
RAM
Disk
Colab AI
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.tree import DecisionTreeClassifier
from sklearn.tree import DecisionTreeRegressor
from sklearn.linear_model import LinearRegression
from sklearn.multioutput import MultiOutputRegressor
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import classification_report
import joblib
import pickle
import warnings
warnings.filterwarnings('ignore')
# read data from csv files
data = pd.read_csv(in_loc + 'crops.csv')
# Preprocess the data
X = data[['temperature', 'humidity', 'rainfall']]
y = data['label']
le = LabelEncoder()
y = le.fit_transform(y)
# Split the data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
Save the fitted transformation
Disk 80.65 GB available
Connected to Python 3 Google Compute Engine backend

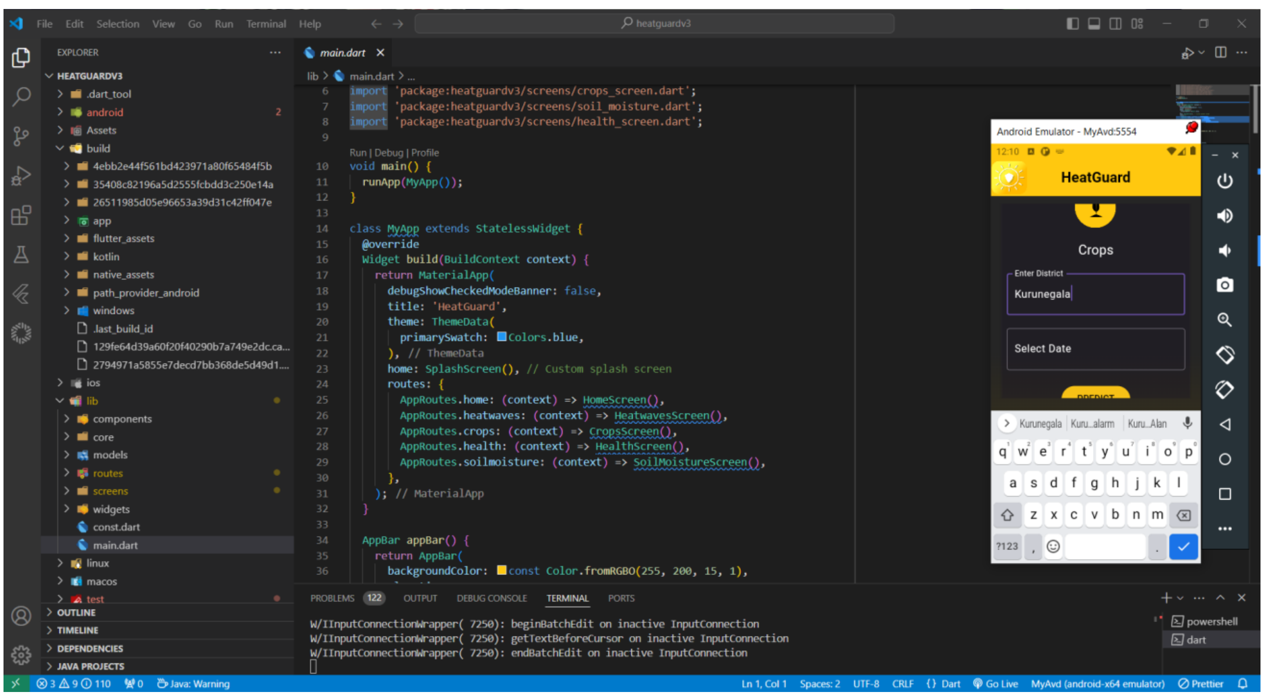

CropRecommendationNotebook.ipynb
File Edit View Insert Runtime Tools Help All changes saved
Comment Share
Files
sample_data
crops.csv
+ Code + Text
RAM
Disk
Colab AI
plt.scatter(data['temperature'], data['label'], label='temperature vs. label')
plt.xlabel('temperature')
plt.ylabel('label')
plt.legend()
plt.title('Scatter Plot')
plt.show()
Scatter Plot
temperature vs. label
coffee
jute
cotton
coconut
papaya
orange
apple
muskmelon
watermelon
grapes
mango
banana
pomegranate
lentil
blackgram
mungbean
mothbeans
pigeonpeas
kidneybeans
chickpea
maize
rice
label
10
15
20
25
30
35
40
45
temperature
data.describe()
Disk 80.65 GB available
Connected to Python 3 Google Compute Engine backend

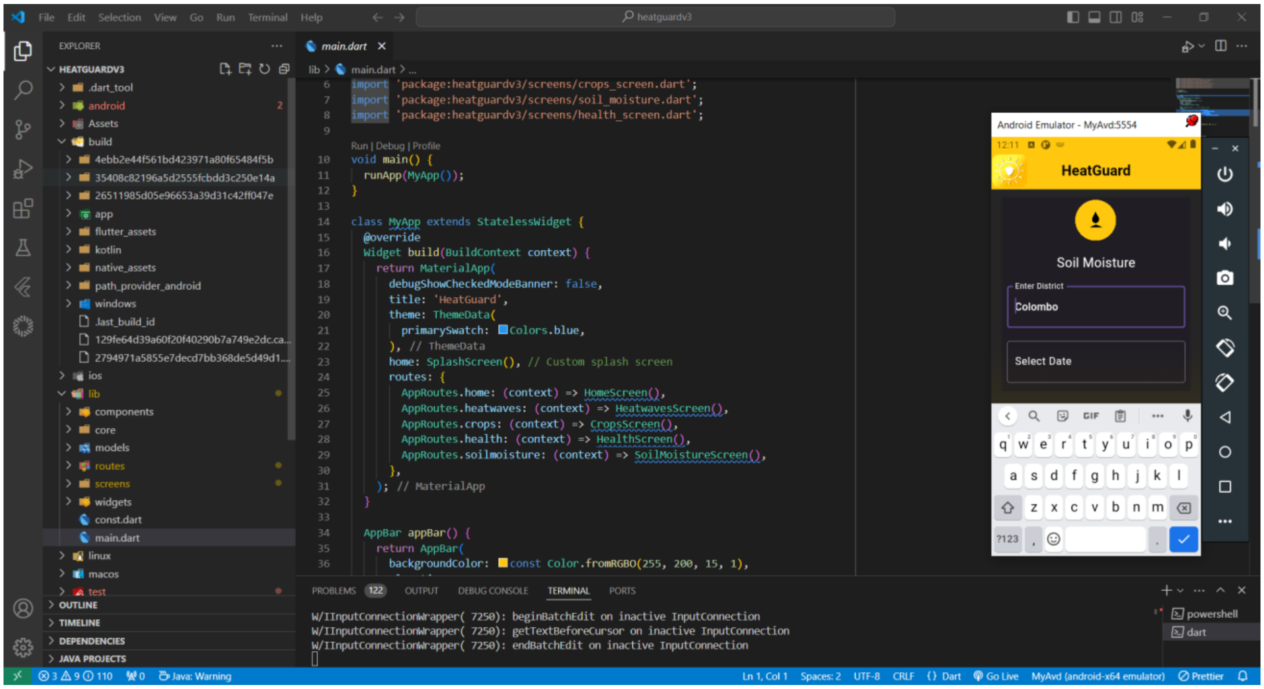




7.3.User Interface


import 'package:heatguardv3/screens/crops_screen.dart';
import 'package:heatguardv3/screens/soil_moisture.dart';
import 'package:heatguardv3/screens/health_screen.dart';
void main() {
runApp(MyApp());
}
class MyApp extends StatelessWidget {
@override
Widget build(BuildContext context) {
return MaterialApp(
debugShowCheckedModeBanner: false,
title: 'HeatGuard',
theme: ThemeData(
primarySwatch: Colors.blue,
), // ThemeData
home: SplashScreen(), // Custom splash screen
routes: {
AppRoutes.home: (context) => HomeScreen(),
AppRoutes.heatwaves: (context) => HeatwavesScreen(),
AppRoutes.crops: (context) => CropsScreen(),
AppRoutes.health: (context) => HealthScreen(),
AppRoutes.soilmoisture: (context) => SoilMoistureScreen(),
},
); // MaterialApp
}
AppBar appBar() {
return AppBar(
backgroundColor: const Color.fromRGBO(255, 200, 15, 1),
Android Emulator - MyAvd:5554
HeatGuard
Texas
Max: 24° C
Min: 23° C
Wind: 3m/s
Humidity: 68%
Heatwaves
Crops
Soil Moisture
Health
W/IInputConnectionWrapper(7250): beginBatchEdit on inactive InputConnection
W/IInputConnectionWrapper(7250): getTextBeforeCursor on inactive InputConnection
W/IInputConnectionWrapper(7250): endBatchEdit on inactive InputConnection


import 'package:heatguardv3/screens/crops_screen.dart';
import 'package:heatguardv3/screens/soil_moisture.dart';
import 'package:heatguardv3/screens/health_screen.dart';
void main() {
runApp(MyApp());
}
class MyApp extends StatelessWidget {
@override
Widget build(BuildContext context) {
return MaterialApp(
debugShowCheckedModeBanner: false,
title: 'HeatGuard',
theme: ThemeData(
primarySwatch: Colors.blue,
), // ThemeData
home: SplashScreen(), // Custom splash screen
routes: {
AppRoutes.home: (context) => HomeScreen(),
AppRoutes.heatwaves: (context) => HeatwavesScreen(),
AppRoutes.crops: (context) => CropsScreen(),
AppRoutes.health: (context) => HealthScreen(),
AppRoutes.soilmoisture: (context) => SoilMoistureScreen(),
},
); // MaterialApp
}
AppBar appBar() {
return AppBar(
backgroundColor: const Color.fromRGBO(255, 200, 15, 1),
Android Emulator - MyAvd:5554
HeatGuard
Crops
Enter District
Kurunegala
Select Date
W/IInputConnectionWrapper(7250): beginBatchEdit on inactive InputConnection
W/IInputConnectionWrapper(7250): getTextBeforeCursor on inactive InputConnection
W/IInputConnectionWrapper(7250): endBatchEdit on inactive InputConnection


File Edit Selection View Go Run Terminal Help
heatguardv3
EXPLORER
HEATGUARDV3
.dart_tool
android
Assets
build
app
flutter_assets
kotlin
native_assets
path_provider_android
windows
.last_build_id
ios
lib
components
core
models
routes
screens
widgets
const.dart
main.dart
linux
macos
test
OUTLINE
TIMELINE
DEPENDENCIES
JAVA PROJECTS
main.dart
lib > main.dart > ...
import 'package:heatguardv3/screens/crops_screen.dart';
import 'package:heatguardv3/screens/soil_moisture.dart';
import 'package:heatguardv3/screens/health_screen.dart';
Run | Debug | Profile
void main() {
runApp(MyApp());
}
class MyApp extends StatelessWidget {
@override
Widget build(BuildContext context) {
return MaterialApp(
debugShowCheckedModeBanner: false,
title: 'HeatGuard',
theme: ThemeData(
primarySwatch: Colors.blue,
), // ThemeData
home: SplashScreen(), // Custom splash screen
routes: {
AppRoutes.home: (context) => HomeScreen(),
AppRoutes.heatwaves: (context) => HeatwavesScreen(),
AppRoutes.crops: (context) => CropsScreen(),
AppRoutes.health: (context) => HealthScreen(),
AppRoutes.soilmoisture: (context) => SoilMoistureScreen(),
},
); // MaterialApp
}
AppBar appBar() {
return AppBar(
backgroundColor: const Color.fromRGBO(255, 200, 15, 1),
Android Emulator - MyAvd:5554
HeatGuard
Soil Moisture
Enter District
Colombo
Select Date
PROBLEMS 122 OUTPUT DEBUG CONSOLE TERMINAL PORTS
W/IInputConnectionWrapper(7250): beginBatchEdit on inactive InputConnection
W/IInputConnectionWrapper(7250): getTextBeforeCursor on inactive InputConnection
W/IInputConnectionWrapper(7250): endBatchEdit on inactive InputConnection
powershell
dart
Java: Warning
Ln 1, Col 1 Spaces: 2 UTF-8 CRLF {} Dart Go Live MyAvd (android-x64 emulator) Prettier

8. CONCLUTIONS

IT20145552 – Dissanayaka. D. M. S. M

In conclusion, the development and implementation of the Heat Vulnerability Index (HVI) tailored to Sri Lanka represent a significant advancement in our understanding of heat vulnerability dynamics in the country. Through a systematic process of data collection, indicator selection, and index calculation, we have created a comprehensive tool for assessing vulnerability to heatwaves across different regions and communities. The HVI captures the multidimensional nature of vulnerability, integrating socio-economic, demographic, and environmental factors to provide a nuanced understanding of the challenges posed by extreme heat events.

The testing phase of the HVI has further validated its reliability and utility, demonstrating strong correlations with observed heat-related health outcomes and highlighting areas of high vulnerability that require targeted interventions. The implementation of the HVI into decision making processes and policy frameworks holds promise for enhancing climate resilience and guiding adaptation strategies in Sri Lanka. By integrating HVI insights into sectoral plans, policies, and strategies, decision-makers can prioritize investments, allocate resources effectively, and develop targeted interventions aimed at reducing vulnerability and building resilience at national, regional, and local levels.

However, challenges remain in ensuring the long-term sustainability and impact of the HVI. Continued efforts are needed to strengthen data collection systems, enhance stakeholder engagement, and foster collaboration among diverse actors involved in climate adaptation and resilience-building efforts. Monitoring and evaluation mechanisms must be established to track progress, identify gaps, and refine the HVI methodology over time. Moreover, community engagement and empowerment are essential for ensuring that vulnerable populations are actively involved in decision-making processes and adaptation efforts, fostering inclusive and equitable resilience-building initiatives.

In conclusion, the Heat Vulnerability Index offers a valuable tool for enhancing our ability to understand, assess, and address heat vulnerability in Sri Lanka. By harnessing the insights provided by the HVI and working collaboratively towards building resilient and sustainable communities,

IT20142728 – Ranawaka. T. D

In conclusion, the development and implementation of the soil moisture forecasting and crop Recommendation component shows an important step in our capacity to control agricultural resilience and reduce the effects of heatwaves in Sri Lanka. By means of methodical data gathering, preprocessing, and modeling approaches, we have developed a comprehensive instrument capable of forecasting soil moisture content and suggesting appropriate crops in different climate conditions.

The crop recommendation and soil moisture forecasting component went through testing to confirm its usefulness and dependability. It showed good correlations with actual crop yields and identified high-risk locations that need for focused interventions. We have hope to enhance climate resilience and directing adaptation plans in Sri Lanka's agriculture sector by including this element into frameworks for agricultural development and decision-making.

Ensure the component's longevity and affect is still difficult, though. Sustained efforts are required to improve stakeholder involvement, improve data collecting systems, and cultivate cooperation among the many players involved in agricultural adaptation and resilience-building initiatives. Developing monitoring and assessment procedures is necessary to monitor development, spot gaps, and improve modeling methods over time.

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