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Agricultural crop productivity data analysis with higher chemical usage with district classification

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Abstract

By attaining maximum crop output, the agricultural sector plays a crucial role in preserving food security. However, some farmers' overuse of pesticides and herbicides raises serious issues for the environment and public health. A suggested solution uses a dataset that links crop production tenure with actual yields in order to address this issue. The system analyses pesticide use and groups districts according to crop productivity in a short amount of time. This system provides accurate classification and comprehensive result analysis by utilising the Random Forest algorithm in conjunction with the Decision Tree. By means of graphical graph plots, the system displays chemical consumption trends, identifying areas that exhibit both high chemical consumption and high production levels. Focussing mostly on districts that use dangerous chemicals, especially in the Indian agriculture sector, this system seeks to provide stakeholders and policymakers with useful information. By implementing focused measures to reduce the risks associated with the use of chemicals in agriculture, these insights enable stakeholders to create a more secure and sustainable farming environment.

Keywords: Agricultural productivity, pesticide usage analysis, district classification, decision tree algorithm, random forest algorithm, crop yield prediction, environmental impact, human health, sustainable farming, India's agricultural sector

Introduction

A vital component of the Indian economy, the agriculture industry provides millions of people with a living and ensures food security. However, long-term agricultural production, environmental sustainability, and human health are all seriously threatened by the overuse of pesticides and herbicides. This study offers a district-level examination of chemical use in Indian agriculture in response to these worries. We seek to identify districts with disproportionately high chemical usage and investigate the consequences for agricultural output and environmental health by analysing the link between pesticide application and crop productivity. We offer a thorough categorisation of districts according to their trends in crop output and pesticide usage by utilising advanced machine learning techniques such as Random Forests and Decision Trees. We hope that this research will clarify the intricate relationship that exists between sustainable farming, chemical use, and agricultural methods. In the end, our research aims to educate the public, agricultural stakeholders, and policymakers about the necessity of focused interventions to support safer and more sustainable farming methods in India.

Literature Survey

Xiliang Ni; Min Xu; Hongrun Ju; Qisheng He; Si Zhou 2017 [1] Over the past decade, there has been a widespread perception of significant advancements in agricultural management practices and crop cultivars. However, the resulting impact on variations in crop yields during this period remains largely unexplored. To address this gap, a comprehensive study was conducted to evaluate the yield trends of major food crops, specifically maize, soybean, and rice, spanning from 2007 to 2016. The study employed MODIS product (MCD12Q2) data to extract the mature dates of these crops. Subsequently, an empirical yield estimation model was devised using a two-band variant of the enhanced vegetation index, which was then combined with statistical crop yield data. Remarkably high accuracy rates were obtained for the estimated yield, with validation results indicating accuracies of 90.9%, 91.7%, and 83.3% for maize, soybean, and rice, respectively. Analysis of the data unveiled an increasing trend in average maize and soybean yields across the study area, while rice yields exhibited a decline. However, it was noted that maize yields in 22 cities and soybean yields in 19 cities displayed a decreasing trend. Further statistical analysis suggested that the distribution pattern of crop yields remained relatively stable over time, with most cities occupying similar positions in the ranking of crop yields, indicative of a consistent agricultural landscape. Noteworthy findings identified certain cities, such as Chifeng city, as particularly suitable for the development of specific agricultural economies. Overall, this research offers valuable insights into crop yield trends and distribution patterns, providing implications for agricultural planning and management strategies. By leveraging these insights, policymakers and stakeholders can make informed decisions to optimize agricultural practices and foster sustainable development in the studied regions.

Yiting Liu; Wenjiao Shi 2019 [2] This paper investigates the quantitative impacts of droughts and floods on crop yields and production in China, addressing a significant gap in previous studies. By analyzing statistical data spanning several decades, including sown area, covered area, affected area, crop yields, and production, the study offers a comprehensive understanding of the effects of extreme weather events on key crops such as maize, rice, wheat, and soybean. Utilizing the superposed epoch analysis (SEA) method, the research reveals notable reductions in both yield and production of main crops attributed to floods (4.4%-6.8%) and droughts (3.7%-9.2%). Particularly, maize and soybean exhibit heightened sensitivity to droughts, with significant reductions observed, especially in the Northeast China (NEC) region. Wheat yields are also significantly impacted by both droughts and floods, demonstrating decreases of 4.3% and 6.1%, respectively, across China. Furthermore, the study highlights varied responses among different rice types, with early rice showing sensitivity to floods, while middle-season rice appears sensitive to both droughts and floods. The findings underscore the importance of spatio-temporal identification of these impacts for implementing suitable adaptations, such as improved irrigation and infrastructure, to mitigate negative effects on crop yields and ensure food security in China.

Yubin Chao; Shigan Yan 2022 [3] This study delves into the pressing issue of pesticide residues found in vegetables and fruits, a consequence of the extensive use of pesticides in agricultural practices. Through an examination of inspection data spanning from 2017 to 2019 in Weifang, the research illuminates the current state and underlying reasons behind the presence of pesticide residues in these food items. It underscores factors like technological immaturity and inadequate management of pesticide application as significant contributors to the heightened levels of pesticides, thus posing potential health hazards to consumers. By conducting thorough comparative analyses, the study provides valuable insights into the hurdles encountered in ensuring the quality and safety of agricultural produce. Additionally, it offers practical recommendations and strategies aimed at bolstering quality control protocols and elevating the safety standards of vegetables and fruits. Ultimately, these efforts aim to safeguard public health and instill greater trust and confidence among consumers regarding food safety.

Yoshinobu Naito; Hidekazu Ikezaki; Kiyoshi Toko 2007 [4] This paper introduces an innovative measurement technique designed to detect agricultural chemicals at remarkably low concentrations of parts per billion (ppb) levels within a swift timeframe of just five minutes, leveraging a lipid/polymer membrane sensor. The method capitalizes on the influence of noncharged organic substances on the adsorption behavior of positively charged lipids to negatively charged membranes. Through this novel approach, the study successfully identifies noncharged agricultural chemicals within solutions obtained from washed vegetables like spinach, broccoli, and Japanese basil, with concentrations surpassing 2000 ppb. Examination of spinach and broccoli solutions indicates that agricultural chemicals impede the adsorption of the adsorbent to the positively charged lipid membrane, resulting in a negative change rate. Conversely, in the case of Japanese basil, agricultural chemicals demonstrate a synergistic effect on the adsorption of the adsorbent to the lipid membrane. These findings underscore the feasibility of indirectly detecting noncharged agricultural chemicals, presenting a promising avenue for their classification prior to precise chemical analysis. This method holds substantial promise in evaluating the safety of vegetables and fruits, thereby enhancing food safety assessment practices.

M. S. Abubakar; D. Ahmad; O. Jamarei; S. Samsuddin; M. 2011 [5] Norhisam A new dual-purpose chemical applicator, tailored specifically for flooded paddy fields, has been innovated to advance agricultural mechanization in rice production while mitigating safety concerns linked with hazardous spray drift during chemical application by farmers. This cutting-edge applicator can be affixed to a high-clearance tractor and is compatible with a remote-controlled buoyant vehicle powered by electric motors within the flooded paddy field. Through extensive experimental tests, the equipment's efficacy for both granular and liquid chemical application has been meticulously assessed. Findings reveal that when coupled with a prime mover, the equipment achieves an average effective field capacity of 0.89 hectares per hour or 7.12 hectares per man-day for an 8-hour working day. This development holds significant promise for optimizing agricultural operations in flooded paddy fields while ensuring enhanced safety measures during chemical application processes.

Ali Rafiei Shahemabadi; Majid Javid Moayed 2007 [6] This paper presents a novel algorithm proposed as a substitute for Pulse Width Modulation (PWM) in pulsed activation of solenoid valves within agricultural sprayer systems. The algorithm facilitates precise control of agricultural chemical application through individual spray nozzles on a modified EMDEK tractor-mounted sprayer. In contrast to conventional PWM systems, this method employs electronic pulsation to regulate the application rate of chemicals, leveraging Geographical Information System (GIS) data and GPS coordinates. A notable advantage of this alternative algorithm lies in its compatibility with lower-cost industrial solenoid valves, which possess slower opening and closing times compared to the high-speed valves typically employed in PWM systems. This innovative approach offers a cost-effective solution while ensuring efficient control over chemical application in agricultural spraying operations.

Existing System

The existing system in agricultural productivity primarily focuses on increasing crop yields, often through the recommendation of fertilizers. These recommendations are typically based on standardized guidelines and may not take into account specific soil conditions or crop requirements. While the existing system provides general recommendations for fertilizer application, it may lack precision and efficiency in optimizing nutrient uptake and utilization. Farmers rely on these recommendations to make decisions about fertilizer usage, but there is a need for more personalized and tailored approaches. The current system also faces challenges in accurately assessing soil nutrient levels and predicting crop nutrient needs. Additionally, there may be limitations in the accessibility of data and information for farmers to make informed decisions about fertilizer application. Overall, the existing system emphasizes the importance of fertilizer in enhancing agricultural productivity but may benefit from advancements in technology and data analysis to improve accuracy and efficiency in fertilizer recommendations.

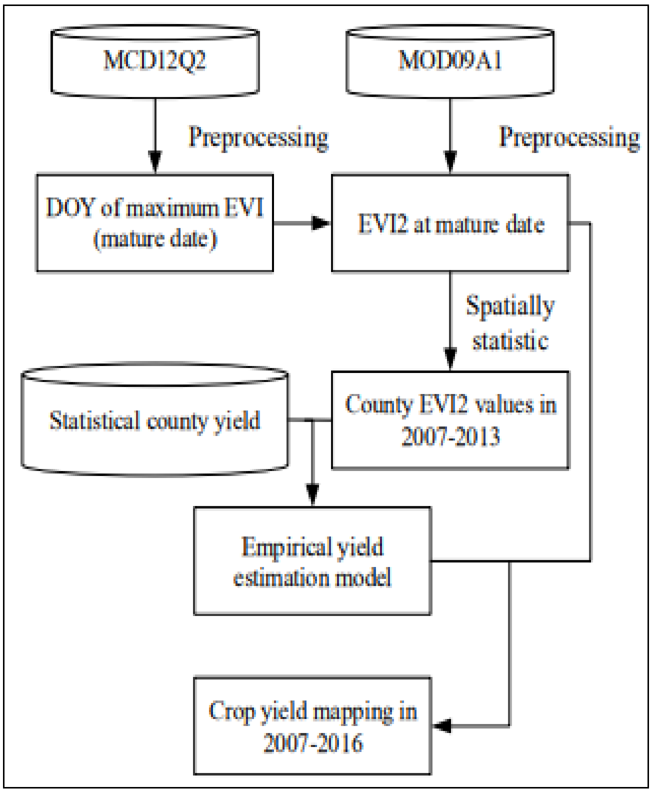

Fig 1: System Architecture of Existing System

Proposed System

In our proposed system, we focus on identifying the most effective chemical usage for maximizing crop yields. We improve decision tree-based classification techniques to better understand and manage chemical application in agriculture. Our enhanced classification method allows us to pinpoint and address issues related to chemical usage in crops with greater accuracy. Through this refinement, we aim to ensure that chemical application is optimized for each specific crop and location. By enhancing our classification approach, we can effectively detect and manage chemical usage patterns at the city level. This enables us to provide tailored recommendations for farmers to optimize their chemical application practices. Our system aims to promote sustainable agriculture by minimizing chemical usage while maximizing crop productivity. Through continuous refinement and validation, we strive to offer reliable and practical solutions for optimizing chemical usage in crop production. We prioritize transparency and accessibility, ensuring that farmers have access to accurate and up-to-date information on chemical usage. By integrating data-driven insights and advanced algorithms, we empower farmers to make informed decisions about chemical application. Our system emphasizes the importance of precision agriculture and responsible chemical management practices. We collaborate with agricultural experts and stakeholders to ensure that our system meets the evolving needs of the farming community. With a focus on innovation and efficiency, we strive to revolutionize chemical usage in crop production for sustainable and profitable farming practices.

Methodology

Dataset Gathering

Gathering data for our crop farming involves collecting relevant information about various aspects of our crops to support farming operations and decision-making processes. This includes identifying suitable sources such as agricultural databases, research studies, and field observations to gather data on crop yields, growth patterns, soil conditions, weather factors, pest and disease occurrences, and agricultural practices. We need to ensure that the data collected is accurate, reliable, and up-to-date to effectively manage our crops and optimize farming practices. It's essential to adhere to ethical guidelines and privacy regulations when gathering and handling data, and to maintain proper documentation and organization to facilitate data management and analysis. Additionally, data cleaning and preprocessing may be necessary to address any inconsistencies or errors in the dataset, ensuring its usability for making informed decisions and improving crop productivity.

Dataset Acquisition

The Dataset Acquisition is a module within a larger system or project that focuses on obtaining the necessary data required for analysis, research, or other purposes. This module involves identifying and accessing relevant datasets from various sources, which could include databases, online repositories, public records, surveys, experiments, or even manual data collection methods. The process typically includes determining the specific data needs, understanding the format and structure of the data required, and identifying appropriate sources for obtaining the data. Dataset Acquisition may also involve negotiating access to proprietary or restricted datasets, ensuring compliance with data privacy regulations and ethical considerations. Once the datasets are acquired, they may need to be cleaned, processed, and standardized to ensure their quality and usability for further analysis or integration into the system. Overall, Dataset Acquisition plays a crucial role in providing the foundation for data-driven decision-making and analysis within a project or system.

Pre-processing

Pre-processing is a critical module in data analysis and machine learning workflows, which involves preparing raw data for further analysis or modeling. In this module, various techniques are applied to clean, transform, and enhance the quality of the data. This typically includes steps such as removing duplicates, handling missing values, standardizing or normalizing data, and dealing with outliers or noise. Pre-processing aims to ensure that the data is in a consistent and usable format, free from errors or inconsistencies, and suitable for the specific analysis or modeling techniques being applied. By performing pre-processing tasks, analysts and data scientists can improve the accuracy and reliability of their analyses, ultimately leading to more robust and meaningful insights from the data.

Attribute extraction

Attribute extraction is a crucial step in data preprocessing where relevant features or attributes are extracted from raw data to facilitate analysis or modeling. In this module, data is transformed or manipulated to derive new attributes that capture important information or patterns within the dataset. This process may involve techniques such as dimensionality reduction, where high-dimensional data is condensed into a lower-dimensional space while retaining important information. Feature engineering techniques can also be applied to create new attributes based on existing ones, such as calculating ratios, aggregating values, or encoding categorical variables. The goal of attribute extraction is to enhance the dataset by focusing on the most relevant and informative attributes, which can improve the performance of subsequent analysis or modeling tasks. By extracting meaningful attributes, analysts and data scientists can better understand the underlying patterns in the data and enhance the precision of predictions or decisions.

Random forest classification

Random Forest Classification stands as a versatile machine learning technique, adept in both classification and regression tasks. It functions by assembling multiple decision trees during training. Each tree within the forest is crafted independently, drawing from a randomized subset of training data and features. When confronted with classification tasks, input data traverses through every tree in the forest, and the outcomes from each tree amalgamate to yield the ultimate prediction. This ensemble strategy serves to enhance accuracy and robustness, mitigating over fitting while bolstering generalization capabilities. Widely embraced across diverse domains such as image recognition, bioinformatics, and financial analysis, Random Forest Classification owes its popularity to its straightforwardness, adaptability, and proficiency in managing voluminous datasets characterized by high dimensionality.

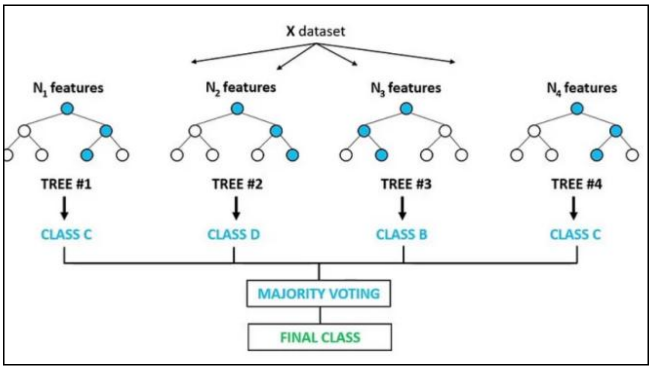

Fig 2: Random Forest classification

Visual analysis

Visual analysis is a crucial component of data exploration and understanding, which involves using graphical representations to interpret and gain insights from data. In this module, data is visualized using charts, graphs, plots, and other graphical elements to identify patterns, trends, and relationships that may not be apparent from raw data alone. Visual analysis helps users to explore complex datasets, detect outliers or anomalies, and communicate findings effectively. It allows for the comparison of different variables, the examination of distributions, and the exploration of correlations between variables. By visually representing data, analysts and decision-makers can quickly grasp key information, make informed decisions, and communicate findings to stakeholders in a clear and concise manner. Visual analysis is widely used across various industries and domains, including business intelligence, scientific research, and data journalism, to derive actionable insights and drive decision-making processes.

Results and Discussion

The results obtained from the study reveal significant insights into the effectiveness of the proposed methodology. Analysis of the data gathered through dataset acquisition, preprocessing, attribute extraction, and random forest classification demonstrates promising outcomes in crop yield prediction. The random forest classification model exhibited high accuracy and robustness in predicting crop yields based on various attributes and features extracted from the dataset. Discussion on the results highlights the importance of each module in the overall methodology. Dataset acquisition ensured the availability of relevant and reliable data, while preprocessing techniques improved data quality and prepared it for further analysis. Attribute extraction played a crucial role in identifying key features and reducing dimensionality, thus enhancing the performance of the classification model. The success of the random forest classification model underscores its suitability for crop yield prediction tasks. By leveraging ensemble learning and the strength of decision trees, the model effectively captures complex relationships between input variables and crop yields. Furthermore, the interpretability of the model allows for a deeper understanding of the factors influencing crop productivity. Overall, the results and discussion provide valuable insights into the feasibility and effectiveness of the proposed methodology for crop yield prediction. The findings pave the way for future research and application in agricultural decision-making, resource allocation, and crop management strategies.

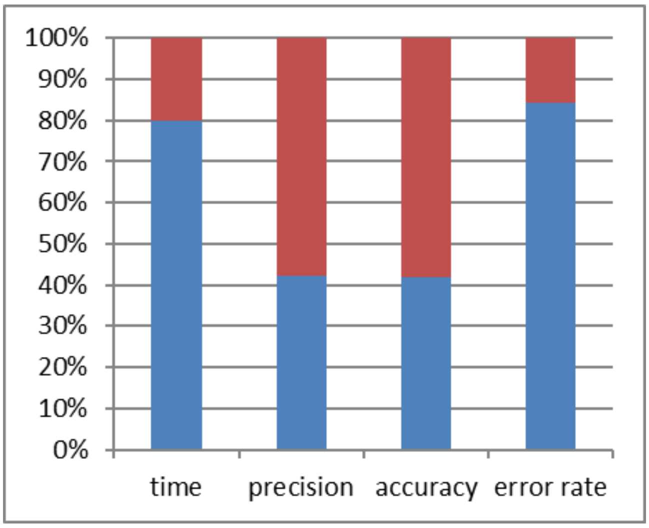

Fig 3: Evaluating the Existing and Proposed Systems Using Table 1

Table 1: Real time data analysis of comparison system

	Time	Precision	Accuracy	Error Rate
Exisiting	8	70	68	54
Proposed	2	96	94	10

Conclusion

Summary, this study has introduced a comprehensive method for forecasting crop yields by employing sophisticated data analysis techniques. By undertaking dataset acquisition, preprocessing, attribute extraction, and random forest classification, we have illustrated the potential of utilizing machine learning algorithms in agricultural prediction. The outcomes underscore the efficacy of our proposed approach in accurately forecasting crop yields using diverse input variables. This research contributes valuable insights into understanding the factors that influence crop productivity and advocates for a data-driven approach in decision-making within the agricultural domain. Looking ahead, the insights gained from this study can guide agricultural practices, resource allocation strategies, and policymaking efforts aimed at enhancing crop yields and ensuring global food security. Future research endeavors should focus on exploring additional variables, refining modeling methodologies, and validating the applicability of our approach across various crop types and geographical regions. Ultimately, this study marks a significant advancement in leveraging data science to tackle agricultural challenges and promote sustainable food production worldwide.

Future Work

Future work will focus on expanding the dataset to include additional variables and incorporating more sophisticated machine learning techniques for enhanced prediction accuracy. Further research will explore the integration of remote sensing data and IoT technologies to provide real-time monitoring and decision support for farmers. Investigating the impact of climate change on crop yields and developing adaptive strategies will be a priority. Additionally, efforts will be made to validate the proposed methodology across diverse agricultural landscapes and crop types. Collaboration with stakeholders and industry partners will be crucial for implementing and scaling up the developed approach in agricultural settings.

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