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RESEARCH ARTICLE

Predictive analysis, data visualization and artificial intelligence tools for agricultural research and communication

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Abstract

Data Science offers powerful tools that predict and promise to enhance crop yields, optimize the farm resource utilization. Artificial Intelligence (AI) can perform tasks that typically require human intelligence, which encompasses a wide range of applications in agriculture starting from seed selection to robotic harvest. Synergy between data science and AI will grow strong to drive technological advancements and shape the future of agriculture sector. This paper presents application of few data science and AI tools in agriculture. Trends, patterns and variations in cost, benefit and returns from crop like Paddy, Groundnut, Sugarcane, Cotton and Maize across different states from 2011 to 2020 were analysed through data visualization. An experimental attempt was also made through web scrapping to understand the United States consumer preference towards the brands (Spice Train, Tellicherry), quantity (11 and 14 oz) and price (15-25 USD package) of pepper. Predictive modeling had shown that the export of pepper may fluctuate over the years while export of basmati rice, cashew nuts and tea will gradually increase for the next few years. High-definition images of tomatoes of different shape, colour, size were used to train the algorithm and tested for identification and classification of tomatoes and images of FAW infested maize were trained and tested for deduction accuracy, which was 82.5 %. Prediction accuracy will increase when the algorithm is trained with large number of images. AI avatars are widely used in social communication for various purposes like short communications, storytelling and documentation, which will be also used effectively for agricultural research communication and learning purposes.

Keywords: data visualization; generative AI; image processing; TS price forecasting; web scrapping

Introduction

In recent years, the agriculture sector has been experiencing a technological transformation driven by Artificial Intelligence (AI) and Big Data Analytics. These technologies have emerged as powerful tools that predict and promise to enhance crop yields, optimize the farm resource utilization and address the challenges of feeding a growing population. Data science is the practice of collecting, processing, analyzing and interpreting data to gain valuable insights and inform decision-making. By integrating skills from various domains, including statistics, computer science and domain expertise, data scientists use techniques such as data mining, machine learning and data visualization to extract meaningful information from large and complex datasets. These analytics uncover the patterns, trends and correlations that can be used to solve real-world problems and well-informed decision making (1).

In addition, AI can perform tasks that typically require human intelligence, which encompasses a wide range of applications, from natural language processing and computer vision to robotics and autonomous systems. Machine learning (ML), a subset of AI, focuses on creating algorithms that allow computers to learn from data and make predictions or decisions without explicit programming. Deep learning, a subfield of machine learning, has been particularly transformative in tasks like image and speech recognition. Together, data science and AI have revolutionized several industries including agriculture to harness the power of data to automate processes, improve efficiency and make data-driven decisions that can lead to innovation and competitive advantages. The synergy between data science and AI will grow strong to drive technological advancements and shape the future of how we interact with technology and information. Data science has several applications in agriculture starting from crop variety selection, sustainable farming practices, precision irrigation, crop monitoring, pest and disease detection, weather forecasting, crop yield prediction, market analysis for risk assessment and insurance (2). These applications help farmers to increase crop yields and the agro firms to optimize their operations, reduce resource wastage and make market decisions (3). This article presents the applications of AI, data visualization and data Analytics in agriculture to showcase how they are reshaping the future of farming.

Data visualization involves representing complex data sets in visual formats, such as charts, graphs, maps and interactive dashboards. This visual representation simplifies the understanding of data patterns, trends and relationships, enabling users/ consumers in agriculture, including farmers, agronomists and researchers, to gain valuable information (4). Data visualization also helps to present the underlying facts visually by curating data into forms that are easier to understand. It highlights the trends and outliers, removes the noise from data and provides useful information from complex data. However, effective data visualization is a challenging task of balancing between data and visual representation. Simple graphs are too usual to attract the readers and do not make an impactful point and on the other side a too detailed visualization could fail at conveying the right message. Data-driven insights will provide a clear understanding of sustainable farming practices through optimizing resource use, reducing chemical inputs and minimizing environmental impact.

Predictive modelling using ML algorithms can forecast crop yields, market prices and weather conditions. ML can process historical and real-time weather data to provide accurate forecasts, helping farmers to optimize planting and harvesting schedules, manage water resources and mitigate the impact of extreme weather events. Price forecasting using AI algorithms can assist farmers in making appropriate decisions about when and where to sell their products for best price based on data on market trends, demand, supply and price. Thus, farmers use these predictions to make informed decisions about planting, harvesting and selling their produce, thereby minimizing risks and maximizing profits (5).

Image processing especially through smart mobiles is used in numerous applications across industries including healthcare, entertainment, agriculture and computer vision (6). AI driven machine learning models can process images of crops to detect signs of pest infestations or diseases and enable timely interventions, such as identification of pest and diseases, targeted pesticide application, to prevent crop damage. Similarly, ML algorithms can guide automated harvesting machines to identify and pick ripe fruits or vegetables, grade and sort harvested produce based on size, colour and quality. This ensures the homogenized products reach the market.

The rapid advancement of AI has enabled widespread digital transformation and given rise to avatars and computer-generated universes that promote intense social connectivity (7). Generative AIs are digitally created representations of human individuals, animals, birds or any creatures that use artificial intelligence to bring them to lifelike experience. These avatars are dynamic and designed to mimic human behaviours and expressions which are reshaping the communication in numerous industries by offering customised interactions, improving service efficiency, providing rich conceptual insights, adapting conversations and responses based on user data.

Material and Methods

This paper presents the applications of modern data science tools specifically on visualization of the large data sets and creating dashboard for better communication; application of predictive modelling to analyze the trend and prediction in export of agricultural commodities. In addition, it presents the imaging technique in pest damage identification and sorting of vegetables. Further, creation of few generative AIs and their features are presented which can be used in agricultural research and communication.

Data visualization

Data visualization is another form of visual art which quickly show the trends and outliers in a massive data in the database. The study utilized Tableau for data visualization and to graphically analyze the cost and returns of various crop cultivations across different Indian states from 2011 to 2022. The primary focus is on paddy, maize, cotton, sugarcane, urad (black gram) and groundnut crops. Data were sourced from the Directorate of Economics and Statistics (DES), Department of Agriculture and Farmers Welfare, Government of India. The data were imported from Excel to Tableau for visualization, creating interactive charts and dashboards to elucidate trends, patterns and anomalies in agricultural costs and returns.

Web scrapping

Among the several marketing platforms, e-commerce is the most suitable for both sellers and consumers in urban areas with the development of information and communication technology. Internet use has also made e-commerce accessible to many businesses and consumers and popularity of online shopping has grown significantly over recent years (8). To analyze the data captured in the e-commerce website pages, Beautiful Soup, a Python web scrapping library was used. It extracts data from HTML and XML files, analyses data in these files to generate a parse tree for web pages, which makes the data extraction easy (9). Web scraping requires two parts, namely the crawler and the scraper. The crawler is an artificial intelligence algorithm that browses the web to search for the data required by following the links across the internet. The scraper, on the other hand, is a specific tool created to extract data from the website. The design of the scraper can vary greatly according to the complexity and scope of the project so that it can quickly and accurately extract the data. The Beautiful Soup object has been created in Python script and the HTML data in the selected web page was scraped off and stored in spreadsheet. Web Scraping can be used to periodically extract the data on price, description, images, reviews, rating etc from various e-commerce websites for continuous analysis to support decision making for effective marketing.

Predictive modelling

Machine learning algorithms use statistical/mathematical models and algorithms to analyze data and make predictions, enabling computer systems to learn and improve from experience without being explicitly programmed. In agriculture, machine learning algorithms can be trained on comprehensive data collected from farms, markets, weather patterns, soil properties, crop growth stages and pest and disease outbreaks. By evaluating the collected data, machine learning models can forecast the growth with high accuracy (10, 11). Forecasting the variables can be achieved using a broad spectrum of ML techniques, including Artificial Neural Networks (ANNs), Support Vector Machines and Random Forests. However, the present study experimented with a simple time series algorithm namely Auto ARIMA. It's a popular

time series forecasting method used to model and make predictions on time-dependent data and was applied to forecast the export of selected agricultural commodities from India.

Image Processing

The combination of increasing global technology penetration and recent advances in machine vision made possible by machine learning has paved the way for diagnosing the images with pest and disease symptoms using python (12). There are several libraries and frameworks namely, TensorFlow, Keras and scikit-learn available in Python that make it easier to perform image processing tasks on large datasets. Libraries like OpenCV can assist with image preprocessing and manipulation. Insect pest damage symptoms and maturity index of tomato were tested for this study.

Generative AI avatars

Traditional machine learning algorithms have been solving important problems for decades and in recent times, photo-realistic avatars, the algorithms are able to consider features such as color schemes, textures and light levels. Reinforcement learning is a method of training an actor or agent to respond to an environment in a way that increases some value, usually through trial and error (13). It is distinct from supervised and unsupervised learning but is often combined with them. Originally inspired by the structure of the biological visual cortex, neural networks consist of a collection of connected units called artificial neurons organized in layers. An avatar generator works by leveraging machine learning and algorithms to analyze user-provided inputs such as a photo or facial features and audio files. Based on the data provided, the model creates an avatar with advanced models, facial expressions, lighting and gait. These artificial faces are created using an algorithm called a “generative anticipation network.” There are free as well as propitiatory AI platform offering the avatar creation. For the present study, avatars were created using D-iD on experimental basis to welcome an event, spelling out a definition, some advice on safe food, an announcement for farmers and forecast advice on market information.

Results and Discussion

Data visualization on cost and returns

Identification of trends, patterns and variations in cost, benefit and returns from crop like Paddy, Groundnut, Sugarcane, Cotton and Maize across different states over the years from 2011 to 2020 were done through data visualization. Tableau's advanced capabilities facilitated the creation of interactive and insightful visualizations, aiding in comprehensive analysis and decision-making (Fig. 1).

1. Upward Trends: Most crops and states exhibit an upward trend in both costs and returns, reflecting increasing production expenses and market prices.
2. State Comparisons: Significant differences exist between states in terms of costs and returns, influenced by local agricultural practices, environmental factors and market conditions.
3. Volatility: Certain states exhibit high volatility in returns, indicating fluctuating market conditions and profitability.

For the saving the visualized form of data (graph), one must sign in to Tableau public server for downloading it in interested format. The formats available are .jpg, .pdf, .ppt and as data and tableau workbook. This software helps in comparison of multiple graphs in the dashboard section that help the analyst to compare various graph of the analysis. Dashboard (Fig. 2.) enables the highlighting feature of one variable in all related graphs combined in the dashboard which directly provides the pattern or relationship during different period or different categories.

Consumer data collection through web scraping

Collection of data from consumers is a challenge and the quality of the data also varies greatly according to the circumstances during data collection. Primary data collection takes longer time and considerable man hours. One alternate way to understand the consumer’s preference is based on their purchase in e-commerce websites. This method allows data collection from distant markets and foreign markets too (Fig. 3). An experimental attempt was made to understand the US

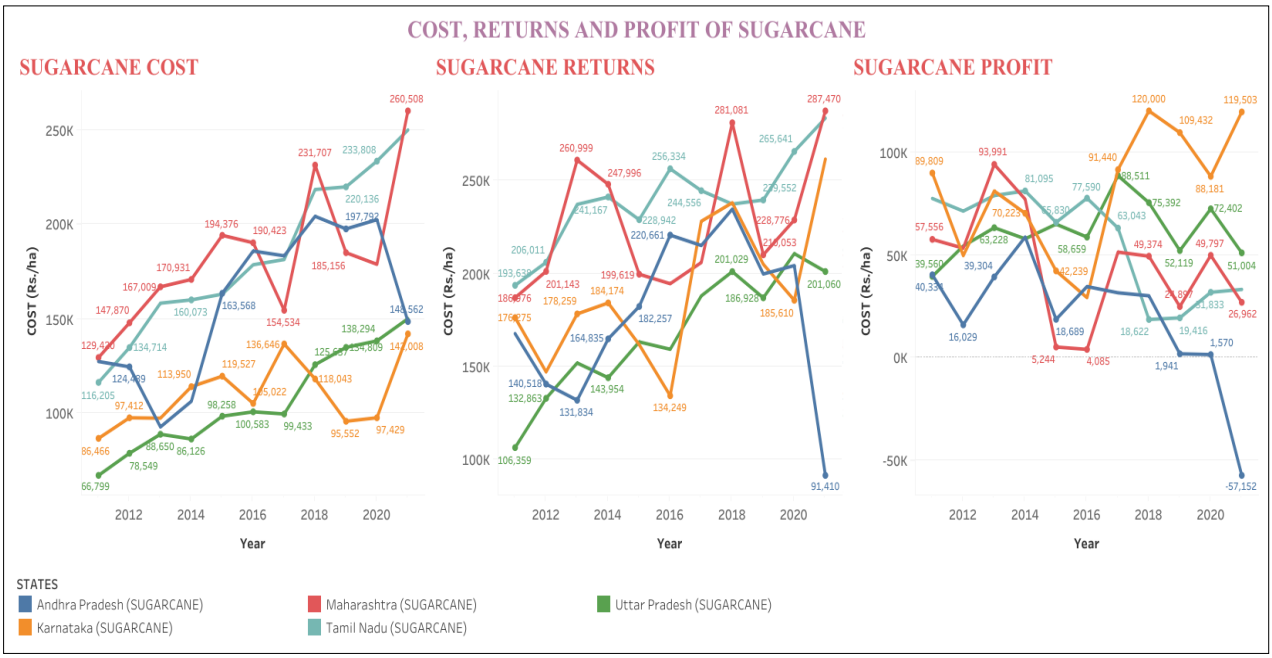

Fig. 1. Cost, returns and profit of Sugarcane from 2011 to 2022.

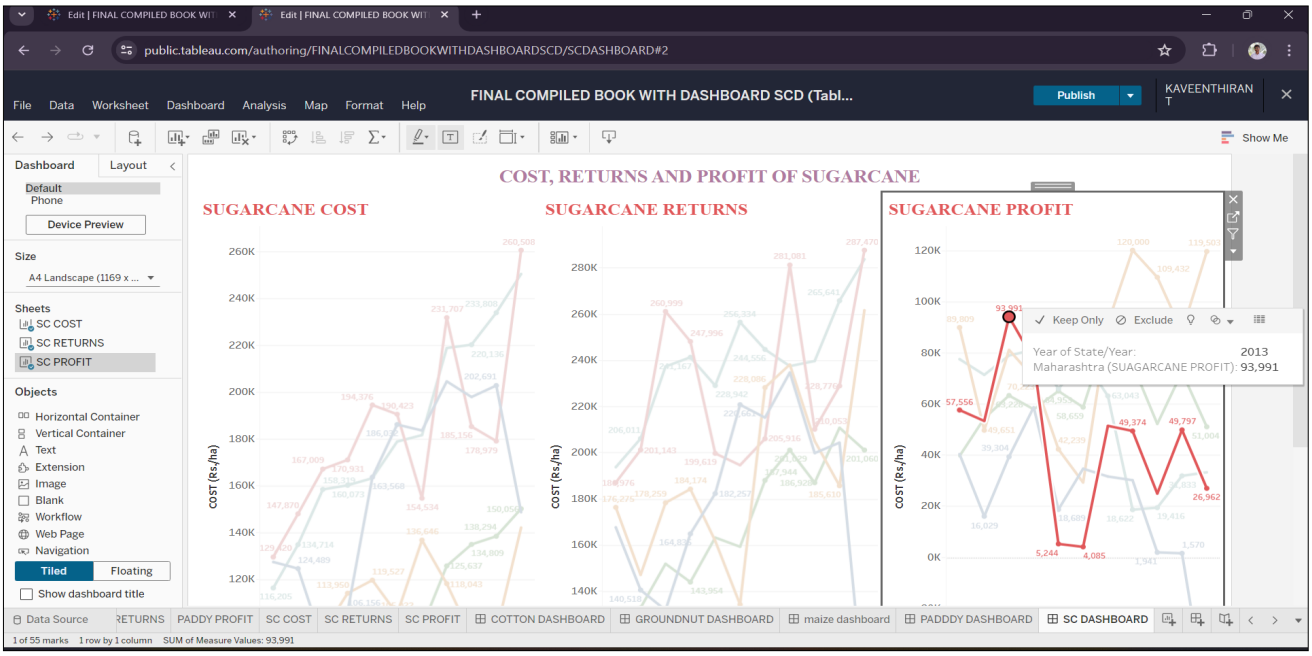

Fig. 2. Dashboard in Tableau visualizing the data of sugarcane production.

Consumer preference towards the brands (Spice Train, Tellicherry), quantity (11 and 14 oz) and price (15-25 USD package) of pepper. Similarly, preferences to basmati rice and cashew nuts were also identified using the data collected from e-commerce portal of the countries concerned. Scrapping was not successful because of added security features in the portal in recent times.

Forecasting the export trend

Data on export of major agricultural commodities were used to predict the future trend and the dynamic graphs were created to visualise these predictions. Export of pepper may fluctuate over the years while export of basmati rice, cashew nuts and tea will gradually increase for the next few years from India presented in Table 1.

The table representation of the export trend will convey a static impression while the dynamic graph will make the viewer to feel the up and down during different period and to draw inferences accordingly. Animated or dynamic graphs on export of tea and cashew nuts can be accessed through the links given below.

https://public.flourish.studio/visualisation/17692346

https://public.flourish.studio/visualisation/17691713/

Sorting and identification

High-definition images of tomatoes of different shape, colour, size (Fig. 4) were used to train the algorithm and then tested for identification and classification of tomatoes in this study. Further, images of Fall Armyworm (FAW) infested maize were trained and tested for deduction accuracy (Fig. 5). The results from the image processing system utilizing a convolutional neural network are promising, with 33 out of 40 images accurately processed and classified. A remarkable outcome has been achieved through the utilization of a convolutional neural network (CNN) in the image processing system. This experiment result, corresponding to an accuracy rate of 82.5 %, demonstrates the robustness and effectiveness of the CNN model in processing and analyzing the diverse visual data. The system's ability to successfully handle the images shows its reliability in detecting and classifying patterns, objects and features within the images. This achievement has significant

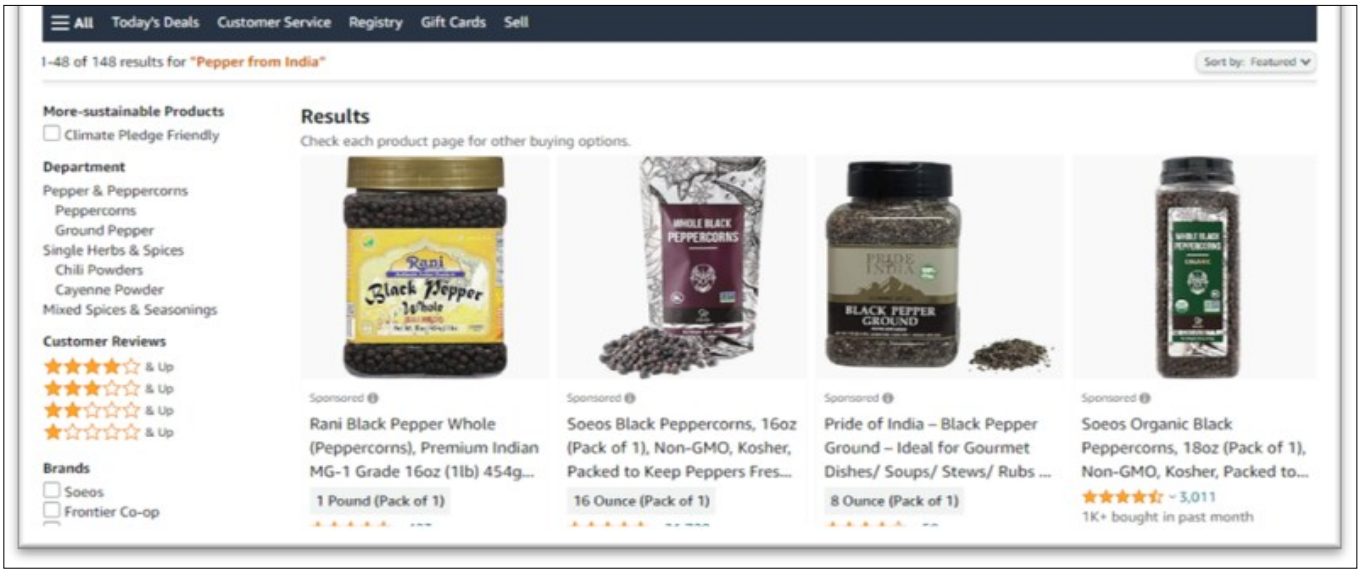

Fig. 3. Selection of products in e-commence website for web scrapping.

Table 1. Forecasting of exports using AutoARIMA (in MT)

Year	Pepper	Basmati Rice	Cashew nut shelled	Tea leaves
2023-24	19831	4567248	49221	136570
2024-25	21842	4842511	51588	204191
2025-26	24917	5149696	48512	204282
2026-27	21992	5198859	49436	204373
2027-28	22068	5268021	50361	204463
2028-29	20143	5286346	51285	204554
2029-30	23218	5297183	52209	204645

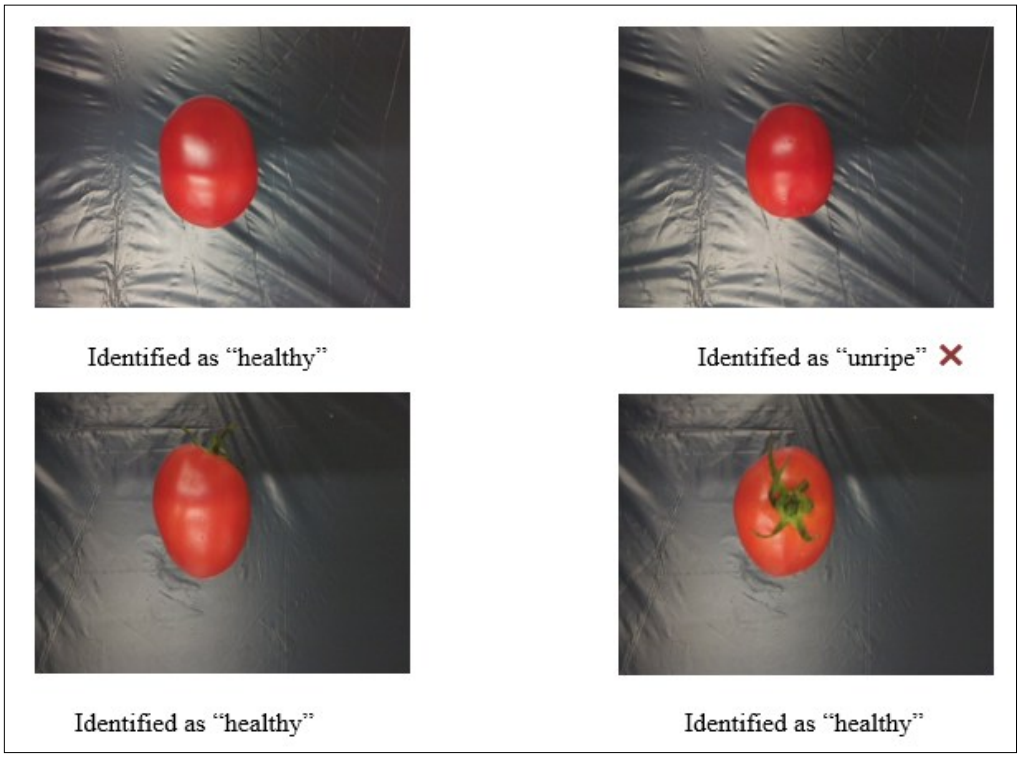

Fig. 4. Image processing and detection of tomato.

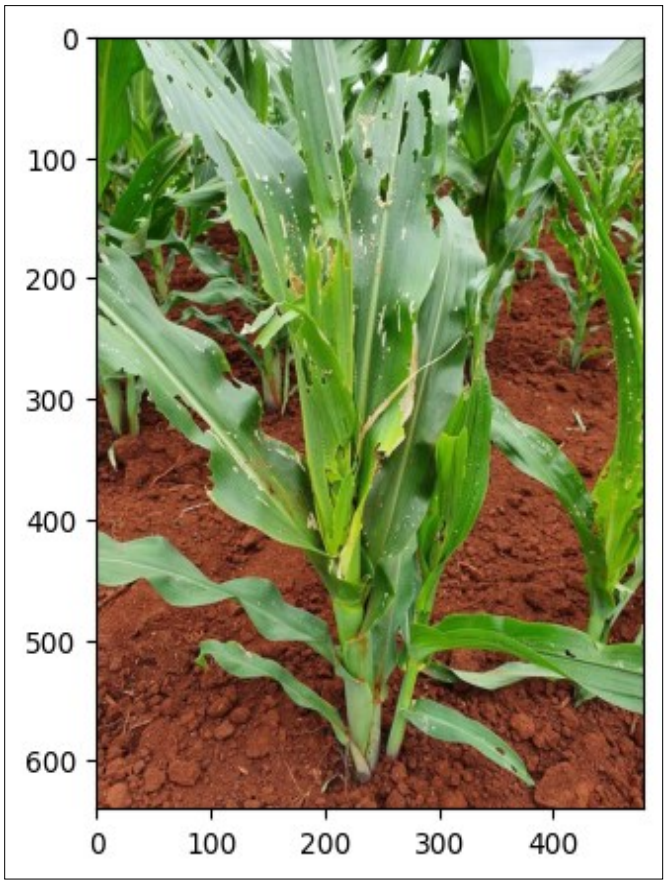

Fig. 5. Image processing and detection of FAW damage in maize plant.

implications for various applications, such as object recognition, image classification and computer vision, showcasing the potential of CNNs in driving innovation and advancements in these fields.

AI avatars for research communication

In recent days, AI avatars are very widely used in social communication for various purposes like short communications, storytelling and documentation of provers etc., Similarly avatars will be used effectively for research communication and learning purposes. Hence, experiments were conducted to create avatars for different purposes and depicted in Table 2.

Constraints

While AI offers numerous benefits to agriculture, they also come with certain limitations and challenges as given below:

1. Cost of Technology
2. Infrastructure and Connectivity
3. Data Quality and Availability
4. Skill and Training Gap
5. Data Privacy and Security Interpretability and Trust
6. Generalization Issues
7. Ethical Considerations
8. Copyright infringement
9. Maintenance and Upkeep

Table 2. Artificial intelligence avatars generated for different purposes

S.No.	AI avatar	Prompting and purpose
1		Prompting was done to create an image of the girl with description on attire, posture and age criteria. Selection of voice and the text were finalized after repeated experiments. This avatar was created to welcome the delegates visiting the data analytics lab.
2		Avathar creation with popular personalities and important leaders were prohibited is usual (free or intermediate) AI creating apps. Use of David Ricardo was not successful. Hence, image of the teacher can use his or her may be used to create an avathar to teach "theory of comparative advantage"
3		Creation of avathar using Nammazhvar was successful and selection of voice and the message were also successfully added. This was created to pass a message on Food Safety
4		Spread of information among farmers by farmers is always effective. In this background, an avatar of a farmer conveying a message to fellow farmers was created. It talks about Weather and Crop Protection Announcement.
5		Dissemination of market prices is always a crutial intervention to benefit farmers to receive better prices. A native farmer speaking the local language to pass the price forecast to the fellow farmers was created.

Conclusion

Potential of data analytical tools is enormous and the same may be utilized in different sectors of agriculture. By updating the modern data science analytical skills, domain experts can significantly contribute to the rapid growth of the agricultural research and outreach. AI Application will continue to grow and at the same time it poses challenges like cost of technology, privacy concerns, authenticity and legal issues associated with the creations.

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Authors' contributions

MP carried out the predictive modelling, generative AI avatars and drafted the manuscript. SS carried out the predictive modelling in weather forecasting and drafted the sub section. CSS carried out the image processing and drafted the sub section. SDS evaluated the features of the generative AI avators and improvised the features. DSK guided the data visualization and provided the overall outline of the draft manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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