K. B. Hebbar* and
Ravi Bhat

Current status of application of digital technologies in plantation crops

The plantation sector in India, comprising crops like coconut, arecanut, tea, coffee, rubber, and oil palm, significantly contributes to the national economy, supporting over 30 million small-scale growers. Despite its importance, the sector faces challenges in resource management, labour shortages, and environmental sustainability. The integration of digital technologies such as IoT, AI, drones, and blockchain is revolutionizing plantation crop management. These technologies enhance resource efficiency, facilitate precise crop monitoring, predict yields, detect diseases, and improve pest control. Additionally, AI-driven tools and big data analytics aid in optimizing irrigation, fertilization, and market strategies. Drones offer advantages in aerial surveys and pesticide application, while blockchain ensures transparency in the supply chain, especially for export-oriented crops. The collaborative efforts between agricultural and technological sectors are paving the way for a more sustainable, efficient, and competitive plantation industry. This integration is crucial for addressing resource limitations and ensuring long-term growth and global market competitiveness in the plantation sector.

THE plantation sector in India plays a vital role in supporting over 30 million small-scale growers and contributes significantly to the nation's economy. Plantation crops, which include coconut, arecanut, tea, coffee, rubber, and oil palm, are a major source of foreign exchange and generate about 6.71% of the total value-added by the horticultural sector. Over the years, resource management, labour shortages, and environmental challenges have complicated crop cultivation. The integration of digital technologies such as IoT, AI, drones, and blockchain is revolutionizing plantation crop management. Precision agriculture enhances resource efficiency, while AI-driven tools aid in yield prediction, pest and disease detection and control. Drones help monitor crop health and facilitate precise pesticide application. Blockchain ensures transparency in supply chains, critical for export-oriented crops. Additionally, big data analytics and remote sensing offer insights into market trends, sustainability, and environmental conditions. Collaborative efforts are underway to further innovate plantation management, ensuring that the sector remains competitive, sustainable, and inclusive.

Historically, as in other developing countries, the plantation crops sector in India has been promoted as a means of foreign exchange earner, and at present they provide sustenance to more than 30 million small growers who are dependent on these crops. The gross value-added by the sector annually amounts to ₹ 328,000 million, which is 6.71% of the total value-added by the horticultural sector. It is noteworthy that, the gross value output generated by the plantation crops during 2012 was ₹ 257,000 million, and there is a marked increase in this respect to the tune of 28%, over a decade. Moreover, the growth is well diversified into the non-traditional and North-Eastern states. Furthermore, plantation crops like coconut and arecanut provide adequate interspaces for intercropping of seasonal crops and thus ensure the food security to a great extent. Their total coverage is comparatively less and they are mostly confined to small holdings. The plantation crops sector in India, in recent times has been characterized by selective state intervention and the removal of tariff barriers, wherein its survival depends on international competitiveness. This sector in the country, dominated by millions of small and marginal farmers and mainly confined to the economically and ecologically vulnerable regions, plays a crucial role as far as the issue of sustainability is concerned.

Resource management is essential in perennial plantation crops for sustainable growth where the crops remain in field for long duration. Many times, the vegetative and reproductive phases are found simultaneously. Under such circumstances, the resources should be available continuously to plants for better growth and yield of the crops. The scarcity of resources over the years makes the management more crucial. Many of the operations like harvesting and spraying are laborious and scarcity of skilled labourers has resulted in delay in operations leading to crop loss and sometimes loss of plants. Because of the placement of canopy at higher level, diagnosis of the disease and pest incidence

is noticed only when the plant is irrevocably affected. It is essential to diagnose any problem in the initial stage for better management of the problem. The application of digital technology which has shown the advantages of the technology for better resource management and ease of doing things, should also be adopted in plantation crops to address some of the above issues.

The integration of digital technologies in agriculture, particularly in the management of plantation crops, has revolutionized the traditional farming practices. Plantation crops such as tea, coffee, rubber, oil palm, and coconut are vital to many economies, particularly in tropical and sub-tropical regions. These crops require careful management to optimize productivity, ensure sustainability, and meet market demands. Digital technologies such as IoT (Internet of Things), AI (Artificial Intelligence), drones, and big data analytics are playing an increasingly crucial role in enhancing the efficiency, productivity, and environmental sustainability of plantation crops.

Precision agriculture

Enhancing the resource-use efficiency is the key idea behind precision agriculture. Attempts are made to supply nutrients and water as per the need of the crops and soil to achieve higher use efficiency. The wider spacing adopted in plantation crops makes the crops amenable for the adoption of drip irrigation and fertigation technologies. The studies conducted over years in coconut and arecanut have revealed about 25 to 50% savings in water and nutrients with similar increase in the yield. The automatic irrigation systems installed in arecanut and banana gardens in parts of Tamil Nadu have not only increased yield by 50% and better quality of crop leading to higher income but also reduced the labour requirement significantly. The digital tools like sensors, satellite or drone-based images could provide real-time data, which help the farmers to adjust irrigation schedules to avoid over or under-watering, apply fertilizers and pesticides more efficiently based on specific crop needs and track the growth stages of crops to ensure timely interventions. These technologies allow farmers to target specific areas in plantations for corrective measures.

Internet of Things (IoT)

This technology minimizes labour-intensive tasks, reduces resource wastage, and ensures that crops are cultivated in optimal conditions. Internet of Things (IoT) enables interconnected devices to collect and transmit data across plantation fields. The automatic irrigation/ fertigation system installed in arecanut and coconut is being monitored by farmers sitting in house through smart mobile phones. In plantation crops, IoT is utilized as soil monitoring system to monitor soil pH levels, moisture regime, and temperature, which provide real-time insights for better crop management. IoT powered weather stations provide localized and accurate forecasts, which help farmers to make decisions about different operations like irrigation, harvesting and applying plant protection chemicals. IoT powered smart irrigation systems measure real-time soil moisture data and automate water application based on need which improves water-use efficiency and reduces the cost of production.

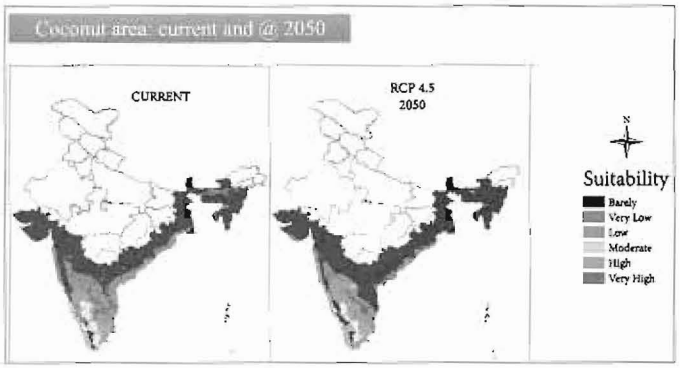
Artificial Intelligence (AI) and Machine Learning (ML)

AI and machine learning (ML) algorithms are used to analyze the vast amounts of data generated by the plantation crops using various gadgets, offering predictive insights for better decision-making. Some of the areas where AI and ML is used are Yield prediction, Disease and pest detection, Weather forecasting and risk management, and Harvesting stage of the crops.

The crop models developed using AI and ML can predict crop yields based on historical data and current conditions about weather parameters, crop growth and practices adopted. These predictions help farmers in proper management of limited resources, crop planning and policy makers for marketing options and distribution of the produce as per the demand at different places. Using these technology, InfoCrop – coconut model is developed to simulate the growth, development and yield of coconut.

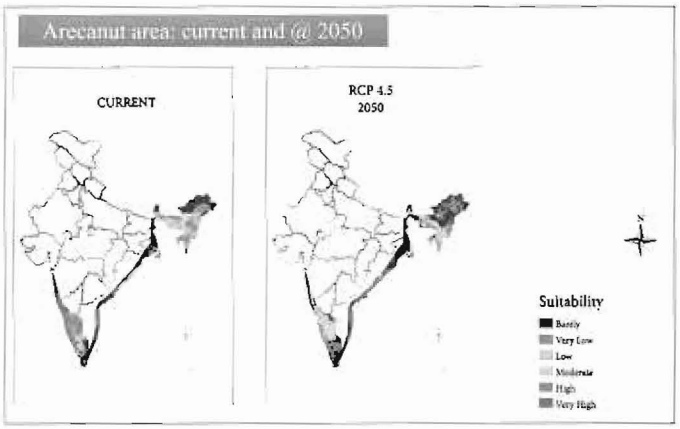
Early detection of disease infection and pest infestation helps in efficient management of the problems. This reduces the cost of management and helps in getting quality crops. AI powered image recognition systems in combination with drone or satellite systems can detect early signs of disease and pest infestations. This helps in early intervention for management which minimizes crop loss and reduces the use of chemicals in agriculture. Weather forecasting and risk management is important for timely understanding the situations for adopting proper interventions. AI systems can analyze historical weather data and predict future climate conditions, viz. rainfall, temperature, humidity etc. This prepares farmers or policy makers for eventual problems like droughts, flood, forecasting the disease and pest events etc. This helps in sustainable production in plantation crops.

MaxEnt model has been used to predict the future climate of the current cultivation area of coconut. This indicated the impact of climate change on the performance of coconut and help the farmers and policy makers for future planning about coconut. The model projected that some current coconut cultivation areas will become unsuitable (plains of South interior Karnataka and Tamil Nadu) requiring crop change, while other areas will require adaptations in genotypic or agronomic management (east coast and the south interior plains), and yet in others, the climatic suitability for growing coconut will increase (west coast). The findings suggest the need for adaptation strategies to ensure sustainable cultivation of coconut at least in presently cultivated areas. Similarly, Biomod2 ensemble model was used to predict future suitable area for arecanut with respect to climate. The model uses different climate parameters. The study suggested that amongst the regions, Karnataka state, which at present has more than 50% area under cultivation, is highly vulnerable and more area is coming under 'very low' and 'low' categories from eastern side. Meanwhile, in north eastern part of the country, a shift in high suitable region from northwest to southwest is observed. Overall, the model prediction suggests that some parts of west and south interior regions of the country warrant immediate



Prediction of coconut area in future climate by MaxEnt model

Use of drone far spraying



Prediction of arecanut area in future climate by Biomod2 model

Mapping after survey by drone far rhinoceros beetle attack

consideration in order to adapt to future climate change, whereas some part of north east can be considered for future cultivation.

In a collaborative effort with ISRO, ICAR-CPCRI is standardizing the technology for diagnosing adulteration in virgin coconut oil using multispectral camera.

ICAR-Directorate of Cashew Research has developed the Cashew Protect website and app for identification of pests and diseases of cashew along with nutrient deficiencies using Artificial Intelligence (AI) and computer vision-based techniques. It is possible to capture data via users on the number and type of pests, diseases and nutrient deficiencies observed in different countries/ regions/districts/taluks during different time periods through this website/app. This will eventually help in early forecasting of these problems and alert farmers in time. Further, it also helps to channelize the efforts and inputs required for efficient management by the concerned agencies in an area/region of the country. ICAR-Indian Institute of Oil Palm Research has developed mobile apps for estimating water requirement in different states, diagnosing different diseases and pests, and nutrient advisor for oil palm.

Coconuts are used for different purposes. Some are used for tender nut water, others for making different products like chips, virgin oil production, copra production etc. Particular maturity stage is required for different products. Gadgets with AI technology can identify the maturity stage and reduce the wastage of the crop due to failure in identifying the proper stage of maturity. Wherever maturity stage is most important for harvest, the AI powered gadgets help in harvesting in right time for better quality products.

Drone technology

Unmanned aerial vehicles, viz. drones have opened newer areas of application in plantation crops. It has helped to overcome the height disadvantage of plantation crops. Use of drones in plantation crops is increasing for aerial surveys, monitoring crop health, and applying fertilizers or pesticides. Drones equipped with high-resolution cameras or multispectral sensors can capture detailed images of the plantation, helping farmers to assess crop health, detect disease outbreaks, pest infestation and monitor growth patterns. Drones can be used to apply fertilizers and pesticides with pinpoint accuracy, reducing chemical usage and ensuring even application across large plantation areas. By providing a bird's eye view of the crop, drones can help estimate yields before harvest, allowing for better planning and resource management. Drone technology is particularly useful in plantations where manual inspection and monitoring would be labor-intensive and time-consuming.

Studies were conducted on use of drone to detect the rhinoceros beetle affected palms in coconut growers. AI

and ML were used for backend analysis. The drone could detect the affected and healthy crowns with the accuracy of about 85%. Similarly, efforts were made to use drone for spraying Bordeaux mixture for fruit rot of arecanut. But the results were not encouraging since the arecanut bunches were below the canopy and the spray could be done only above the canopy. Further, drone parameters, viz. speed of drone, spraying time were standardized for spraying of chemicals and nutrients to canopy of coconut and arecanut.

Blockchain for traceability and supply chain management

Maintaining quality of the product at all stages of crop production is essential especially for export-oriented crops. The products intended for export to different countries should adhere to strict quality standards as fixed by the importing countries. Blockchain technology helps in ensuring the transparency and traceability of plantation crops. Blockchain technology tracks the journey of a product from producer to consumer ensuring transparency in the supply chain. It helps in verifying the authenticity of crops of different nature, viz. organic or natural etc. This is important for meeting the specific market demands for ethical and eco-friendly products. The technology ensures compliance with international regulations, particularly for high-value crops such as coffee, tea, and rubber. By providing an immutable ledger of transactions and events, blockchain enables greater trust between producers, processors, retailers, and consumers.

At ICAR-CPCRI, a digital information system was developed to track the seedling production process from opening to seed nut harvest and seedling production. Each seedling was then labelled with QR codes for ensuring the identity and quality by reading the QR code to know its lineage. Further, a web and mobile friendly app has been developed to facilitate distribution of planting material and other technologies of ICAR-CPCRI. The app allows users to book the requirement online and make cashless payment. On billing, information on client including personal and farm details are collected and uniquely identified with QR code. Distinctive feature of this app is that farmer is tracked and linked for all future transactions and queries benefitting the farmer for farming guidance and allowing the institute to gather geospatial data as research input. Cashew Farmers Tracking System (CFTS) developed by ICAR-Directorate of Cashew Research helps farmers to make informed decisions while identifying and choosing from the wide variety of cashew planting materials. The software will also track the cashew grafts sold to farmers. The CFTS helps the policy makers to monitor the cashew area in the country and the researchers can track the variety spread among the farmers.

Big data analytics

Large amounts of data are generated from plantation crops by various sensors, physical data like yield, market data, images from drone or satellite etc. Such data must be analysed properly for using the data for different decisions to be taken in the plantation management. Big data analytics processes such data to uncover valuable insights, enabling plantation managers to make data-driven decisions. This analysis increases the efficiency of all the resources used and effectiveness of the data collecting devices. Some of the applications of big data analytics are more efficient resource management by optimizing the resource usage like water, labour, nutrients etc. Big data analytics analyzes the market trend and helps farmers and policy makers in improving financial planning and market strategies with prediction of price fluctuations and demand patterns. Data analytics can help assess the environmental impact of plantation crops and practices adopted in plantation crops and suggest improvements to enhance sustainability and reduce carbon footprints. Thus big data analytics can give information on sustainability of the plantation based systems.

Remote sensing

Remote sensing technologies were used initially for crop survey and for monitoring large plantations. With the latest developments in digital technology such as sensors and image processing technology, the utility of remote sensing has been increasing. Remote sensing can play major role in monitoring crop health through detecting variations in crop colour, moisture levels which can indicate the disease or stress. Remote sensing technology will be useful in monitoring soil erosions, nutrient level and moisture in soil in a large area of plantations. The technology also helps in studying impact of climate change on crop productivity.

In 1970s, the remote sensing technology was used for the first time in India for agricultural purpose to estimate the coconut area affected by root (wilt) disease in Kerala. Recently, drone is being used to diagnose the root (wilt) affected palms with a success of more than 75%. By integrating remote sensing data with AI and big data analytics, plantation managers can better anticipate and respond to threats such as drought, pests, and diseases.

Digital marketplace

Digital technologies have also created new opportunities for plantation crop farmers through digital marketplaces. The digital platforms connect producers with buyers, both locally and globally. With this farmers can sell their products without middlemen which can give better profit to farmers. Buyers also can assess the quality and origin of the product. The entire system becomes transparent for both sellers and buyers. The demand and supply can be matched and the products can be transported to areas where the production is minimum and demand is high. ICAR-CPCRI has commercialized technologies on value-addition to coconut. All the entrepreneurs who have taken technologies are selling the produce through e-marketing facilities. In this way products are being sold to faraway places also without much difficulty. Virgin coconut oils, coconut chips, packaged Kalparasa, coconut sugar are seen in the e-market places.

Way forward

One of the major problems in plantation crops is the diagnosis of disease in the crown region. Efforts

are underway in developing drone-based surveillance system and digital eye which can diagnose the disease or pest infestation on the crown of the tall plantation crops, identifying the accurate maturity stage in coconut, which is essential for making value-added products. Efforts are underway for identifying the maturity stage through image analysis or acoustics to make simple gadgets is in progress in collaboration with Engineering Institutes. Harvesting is major issue in plantation crops and robotic climbing machines or robotic hands can ease the operation of harvesting especially in coconut and arecanut. Collaborative works between agricultural and engineering institutes is on the rise to utilize the benefits of digital technology in plantation crops.

SUMMARY

The integration of digital technologies in the management of plantation crops in India is essential for enhancing productivity, sustainability, and competitiveness in the global markets. By adopting precision agriculture, IoT, AI, drones, and blockchain, the sector can address challenges like resource scarcity, labour shortages, and environmental sustainability. These innovations not only improve crop yield and quality but also contribute to efficient resource management and better market access. Moving forward, fostering collaboration between agricultural and technological sectors will be key to ensuring the long-term growth and sustainability of India's plantation crop industry.

For further interaction, please write to:
Dr K. B. Hebbar (Director), ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala 671 124. *Corresponding author: director.cpcri@icar.gov.in