Artificial Intelligence and its applications in agriculture with special reference to the coconut sector

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Introduction

Food security is the major challenge faced by the world, in the wake of swelling population, increase in input and labour costs, depleting natural resources, reducing land size, global climate change, rising temperatures and high incidence of pests and diseases. According to the Food and Agriculture Organization, the global population is expected to increase by two billion by 2050 while only 4% additional land will come under cultivation by then. Smart farming, therefore, becomes the need of the hour. Needless to say, up-gradation of conventional farming techniques in a cost-friendly approach is imperative. Technologies such as Artificial Intelligence (AI), Cloud Machine Learning, Satellite Imagery and advanced analytics can empower small-holder farmers by increasing their income through higher crop yield and greater price control. Today agriculture is seeing a rapid adoption of AI in the form of sensors, drones and robots. A combination of algorithmic advances, data proliferation and the growth in computing power and storage have

transformed AI from a hype to a reality. Cognitive computing in particular is all set to become the most disruptive technology in agricultural services. Drones or unmanned aerial vehicles (UAVs) for instance enabled farmers to move from traditional farm practices to precision farming. A day may come in the not so far future when swarms of autonomous UAVs collect data and perform tasks in tandem.

AI and its applications in agriculture :

AI is typically defined as the ability of a machine to perform cognitive functions we associate with human minds such as perceiving, reasoning, learning and problem solving. It is the study of mental faculties through the use of computational models and makes computers more powerful and useful. Most recent advances in AI have been achieved by applying machine learning to very large data sets. Machine learning - the branch of computer science that is used to construct algorithms which exhibit self learning property – falls under three major types – supervised, unsupervised and reinforcement learning. Popular algorithms in the supervised category include artificial neural networks, decision trees, K-means clustering, support vector machines and Bayesian networks. Unsupervised learning algorithms include COBWEB & DBSCAN. It is like reading a book in an unknown language where the understanding is minimal, but by keeping on reading, patterns are identified and slowly the understanding process starts. Reinforcement learning works on feedback and includes in its ambit genetic algorithms and Markov decision algorithms.

Deep Learning is based on artificial neural networks which try to mimic how the brain processes and makes decisions. The neural networks are trained on data sets to acquire knowledge and apply that knowledge to solve problems. It uses algorithms to self train from the data. It allows additional layers to be developed from the primary data that is collected and uses that information to solve other problems. Fundamentally, neural networks are interconnected networks of nodes parallel to the vast network of neurons in the human brain. Artificial neural networks have come a long way since the first model was proposed by Mc. Culloch and Pitts in 1943. The major types of neural networks are Single-Layer Perceptron (SLP), Multi-Layer Perceptron (MLP), Radial Basis Function (RBF) Networks, Kohonen's Self-Organizing Map (SOM) Networks, Probabilistic Neural Networks (PNN) and Convolutional Neural Networks (CNN).

The major applications of machine learning and AI in agriculture are summarized in the following table and are enumerated below :

Sr.No.	Field of study	Author	Algorithm used
1.	Crop selection and crop yield prediction	Washington *etal* Snehal *etal* Shivnath *etal* Rakesh *etal*	Classification algorithms Neural Networks Back propagation neural networks CSM
2.	Weather forecasting	Y Radhika *etal*	Support Vector machines
3.	Smart irrigation system	Aditya Gupta *etal*	General machine learning algorithms
4.	Crop disease prediction	Rumpf *etal* M.P.Raj *etal* Mehra *etal*	Support vector machines Pattern recognition Artificial neural networks Regression trees Random Forests.

(Source : Karandeep Kaur IJARCCE Vol. 5 Issue 4 April, 2016)

Crop Selection and Crop Yield Prediction : Techniques like artificial neural networks, K-nearest neighbours and decision trees are used in the context of crop selection. A crop selection method called CSM has been proposed by Rakesh Kumar etal (2015) in the International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM). Expert Systems (ES) on variety selection have also proved to be useful tools to select suitable varieties based on the characteristics required by the enduser for getting maximum returns. An expert system, it needs to be mentioned here, is a computer program that uses knowledge and inference procedures to solve problems that are ordinarily solved through human expertise. The main components of an ES are knowledge base, inference engine and user inference. To quote N.Sriram & H.Philip (Expert System for Decision Making in Agriculture), "In agriculture, expert systems are capable of integrating the perspectives of individual disciplines such as plant pathology, entomology, horticulture and agricultural meteorology into a frame work that best addresses the type of adhoc decision making required of modern farmers".

Providing advisory services : It is possible to provide advisory services to farmers on sowing, land preparation, fertilizer application and so on.

Huge volumes of data on historical weather pattern, soil reports, new research, rainfall, pest infestation, images from drones and cameras etc are used to generate insights to improve yield. It may be noted that Microsoft had worked with 175 farmers in Andhra Pradesh and has been successful in achieving 30% higher yield per hectare in comparison to previous year. The pilot project, it must be mentioned here, used an AI sowing app to recommend sowing date, land preparation, soil test based fetilization, optimum sowing depth and more to farmers.

Image based insight generation : Alerts could be generated in real time to accelerate precision farming. Resource optimization is achieved to a large extent. Even ripeness of the green fruits could be assessed and the farmers can plan harvesting according to demands from different markets.

Supply Chain Efficiencies and Credit Risk Management : Companies are using real-time data analytics on data-streams coming from multiple sources to build an efficient and smart supply chain. Crowd-sourced data, algorithms and analytics overcome the credit default problem, the most challenging problem of current supply-chain, to ensure a very low risk operation.

Transition Discovery: Real-time data analysis on multiple data-streams along with crowd-sourced data from producer/buyer marketplaces and transporters feeds their automatic transaction discovery algorithm to obtain high-margin transactions.

Quality Maintenance - Agricultural Product Grading: Automated quality analysis of images of food products is an accurate and reliable method for grading fresh products (fruits, grains, vegetables, cotton etc.) characterized by color, size and shape. Their solution reads the image that a farmer has taken on his phone and determines the product quality in real time, without any manual intervention. Thus computer vision and AI-based automatic grading and sorting creates an international agri-commodity standard for reliable trading across country boundaries.

Agri-Mapping: Deep-learning based satellite image analysis and crowd-sourced information fusion obtains a real-time agri map of commodities at a resolution of 1 sq-km.

Application of drones : Drones are no new technology, but thanks to robust investments and a relatively relaxed regulatory environment, their time has arrived in agriculture. They have the ability for smooth scouting over farm fields, gathering precise information and transmitting data on real time basis. They replace sizeable amount of human drudgery and reduce cost of labour. With a wing span of 1-2 m, drones can in one flight cover approximately 12 square km in 50 minutes. There are four stages in field monitoring by drones:

a) Capture of high resolution images

b) View of data in real time

c) Processing of data in the cloud and translating into useful information

d) Generation of maps providing different types of information.

It must be mentioned here that drones are easy to maintain, largely water resistant and are operational under adverse weather conditions too. According to a prediction of Goldman Sachs, the agricultural sector will be the second largest user of drones in the world in the next five years. There are broadly six options for agricultural drones:

i) Soil and Field Analysis: Drones produce 3D maps for early soil analysis, useful in planning seed planting. In fact soil characterization can be done using proximity sensing and remote sensing. Remote sensing uses sensors in airborne or satellite systems while proximity sensing uses sensors in contact with soil or at a very close range. Characterization of soil below the surface at a particular place is achieved this way. Drones can be used to produce a 3D field map of detailed terrain, drainage, soil viability and irrigation. Nitrogen level management can also be done using drone solutions.

ii) Planting: Drone planting systems can decrease planting costs by 85%.

iii) Aerial Spraying: Drones can scan the ground and spray the correct amount of liquid. Reduction in the amount of chemicals penetrating into ground water is the advantage. UAV sprayer does not need a run way. It can take off and land vertically. Flying at low altitude, the crop spraying can be controlled in any distance range.

iv) Crop Monitoring: As opposed to satellite imagery where images had to be ordered in advance, were imprecise and extremely costly (not to mention disadvantages such as images could be taken only once a day and the quality suffered on certain days, today time series animations have shown the way in crop management.

v) Irrigation: Drones can identify which parts of the field are dry. They also aid calculation of vegetation index and show heat signature. In fact

BLUE RIVER TECHNOLOGY FarmBot Cropin AGVOICE INTELLO LABS GOBASCO

irrigation could be automated with machines trained on historical weather pattern, soil quality and kind of crops to be grown. This is found to result in an increase in the overall yield. In a world moving through water scarcity with 70% of the world's fresh water being used in irrigation, automation could help in better water management and water conservation. Smart devices are being designed on principles of machine learning, working with sensor's data and improving the system over time all by itself. EDYN Garden Sensor is a classic example.

vi) Crop Health Assessment: By scanning a crop using both visible and near field infrared (NIR) light, drone – carried devices can identify which plants reflect different amounts of green light and NIR light. This information can track changes in plants and indicate their health. As soon as sickness is brought to light, farmers can apply remedies. The hybridization of neural network – hyper spectral approach has emerged as a powerful tool for disease detection and diagnosis. Recently the International Water Management Institute carried out trials in Sri Lanka with a NIR. It was observed that a drone with NIR camera can identify stress in a plant ten days before it becomes visible to the naked eye. When a plant goes into stress, photo synthetic activity decreases and that affects the chlorophyll. That is what NIR can detect but human eye cannot until it is more advanced. Needless to say a ten day warning could prevent large scale crop losses. In fact for disease detection and pest attack, the image is captured, preprocessed and transmitted to remote labs. Algorithms can identify diseases and different species with 99% accuracy. This is all the more beneficial in pest identification, nutrient deficient recognition etc.

AI - Powered Chatbots (Virtual Assistants): Currently they are used in retail, travel, media and insurance sectors. Agriculture could also leverage this technology by assisting farmers with answers and recommendations on specific problems.

Case studies of AI start ups in Agriculture

Prospera founded in 2014 in Israel makes predictions with a cloud based solution that aggregates all existing data like soil/water sensors, aerial images etc combined with in-field devices.

Blue River Technology founded in 2011 based in California combines AI, computer vision and robotics. Computer vision identifies each individual plant, ML decides how to treat each individual plant and robotics enables the smart machines to take action.

FarmBot founded in 2011 which helps the farmer to do end-to-end farming all by himself from seed plantation to weed detection and soil testing to watering of plants all by using an open source software system.

AI Sowing App - Microsoft in collaboration with ICRISAT, developed an AI Sowing App powered by Microsoft Cortana Intelligence Suite including Machine Learning and Power BI. The best part – the farmers don't need to install any sensors in their fields or incur any capital expenditure. All they need is a feature phone capable of receiving text messages.

CropIn – Using AI to Maximize per-Acre Value Essentially, CropIn uses technologies such as AI to help clients analyze and interpret data to derive real-time actionable insights on standing crop and projects spanning geographies. Its agri-business intelligence solution called SmartRisk "leverages agri-alternate data and provides risk mitigation and forecasting for effective credit risk assessment and loan recovery assistance.

AgVoice : This system provides a voice-to-data, work flow management service for food and agriculture professionals. They can be deep experts like plant breeders in an R&D environment or professional agronomists or pest control advisors supporting growers. But by combining a uniquely tailored industrial grade voice enabled user experience with a clou based proprietary analytics platform, AgVoice enables users to achieve verifiable fast inspections, reporting and work flow management for the agri-food supply chain more accurately than existing conventional processes.

Intello Labs – Using Deep Learning for Image Analysis - Bengaluru-based Intello Labs provides advanced image recognition technology that can recognize objects, faces, flora fauna and tag them in any image. The company claims to use deep learning algorithms on which a new generation of intelligent applications are being built for applications including agriculture, eCommerce, advertising, manufacturing, and curation.

Gobasco — The Intelligent Agri Supply Chain: Based in Uttar Pradesh, Gobasco employs real-time data analytics on data-streams coming from multiple sources across the country aided with AI-optimized automated pipelines to dramatically increase the efficiency of the current agri supply chain.

Potential applications of AI in coconut

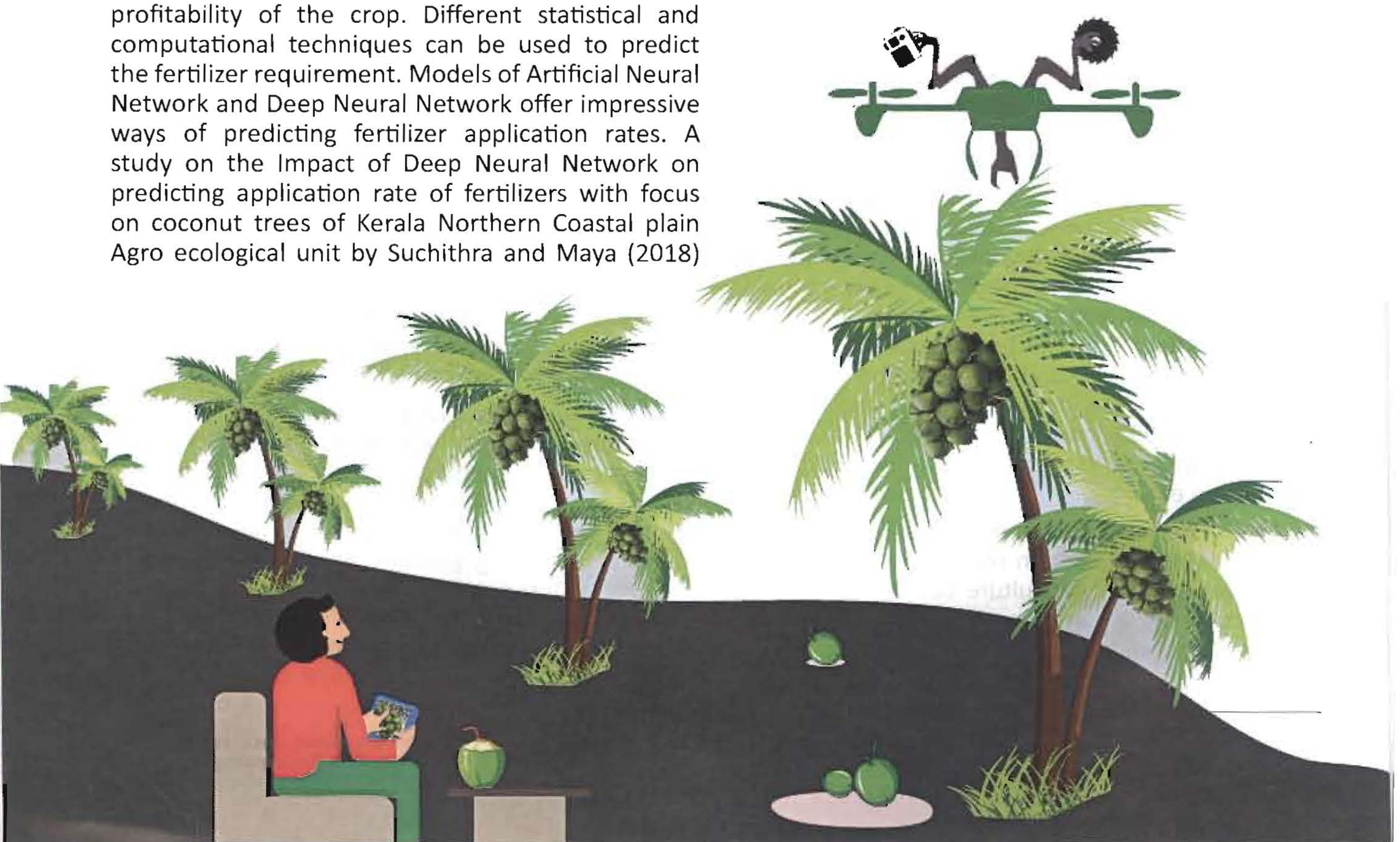
The applications of AI in agriculture discussed earlier are all applicable in coconut. Apart from that uses of AI in coconut processing industry and quality control have huge potential. A number of studies on use of AI in coconut have been undertaken, a few of which are enumerated below.

Fertilizer application in coconut : Timely application of fertilizers in adequate quantities is crucial in determining the productivity and profitability of the crop. Different statistical and computational techniques can be used to predict the fertilizer requirement. Models of Artificial Neural Network and Deep Neural Network offer impressive ways of predicting fertilizer application rates. A study on the Impact of Deep Neural Network on predicting application rate of fertilizers with focus on coconut trees of Kerala Northern Coastal plain Agro ecological unit by Suchithra and Maya (2018) has revealed that the predicted accuracy rate for fertlisers - Urea, Muriate of Potash and lime using Deep Neural network was more than 95% accurate in the coconut sector.

Automated harvesting of coconut through robots : Studies have been done on Colour and contour based identification of stem of coconut bunch in which it was shown by Rajesh et al (2017) that identification of coconut for harvest and cutting of the bunch could be achieved through completely automated robotics. Remote controlled robots have been developed to climb the palm and harvest coconuts.

Modelling of an industrial drying process through artificial neural networks : Assidji et al (2008) have found that the quality issues in grated coconut due to the poor control of product humidity could be solved through a neural network architecture. The rate of rejected products in the first cycle of drying could be reduced to 3%. Such applications could be undertaken in coconut processing in production of various value added products like desiccated coconut coconut milk powder etc.

Identifying adulteration in coconut oil : This is a serious issue in the marketing of coconut oil where high rate of adulteration with cheaper oils and even other chemical substances is undertaken. A study undertaken by Ordukaya and Karlik (2017)



in olive oil showed that adulteration test for quality control in olive oil could be successfully done using ML and electronic nose. Both methods were found to be faster and very cheaper than the classical chemical analysis techniques for identification and classification of quality control in different types of olive oils. The application of similar techniques could be undertaken in coconut oil.

Modeling and forecasting of production : Forecast of production would result in better marketing decisions. Modeling and forecasting of coconut production could be undertaken. Rathod et al (2018) had done modeling and forecasting of oilseed production through AI using Time Delay Neural network and Non Linear support vector regression.

Challenges in implementation of AI in agriculture: The major challenge in implementation of AI in agriculture is the lack of quality data infrastructure. Applications like Deep learning require analysis of lots of good quality data to train the different models. Reliable data is required for getting accurate outputs. Temporal data is hard to get. Most crop specific data can be obtained only once in a year and the data infrastructure takes time to mature, significant amount of time is required to build a robust machine learning model. Lack of familiarity with high tech machine learning solutions in farms is also a constraint. In addition to these, exposure of farming to external factors like weather conditions, soil conditions and presence of pests is quite lot. So what might look like a good solution while planning during the start of harvesting may not be optimal due to changes in external parameters. Exorbitant cost of different cognitive solutions for farming also make AI unaffordable. As far as drones are concerned, safety of operations, privacy issues and insurance coverage questions are paramount. Moreover, the push for more sophisticated sensors and cameras as well as research towards development of drones that require minimal training and are highly automated is yet to take off in a big way.

Pilot Project with the help of CPCRI.

It is in keeping with the spirit of these developments that the Coconut Development Board is planning to team up with the CPCRI for the project "Pest and disease surveillance on coconut palms by unmanned aerial vehicle". The objectives of the project as stated in the proposal include :

a) To develop an early detection system for surveillance of important diseases and pests of coconut palms using real time images captured through multi spectral / hyper spectral camera fitted to a UAV.

b) To determine the feasibility of real time spot delivery of biorationals / bioagents to the pest or disease affected palms.

Needless to say, its practical utility will include surveillance for pests and diseases in places where manual surveillance is difficult like valleys or remote islands. The net result will be that thousands of coconut trees can be saved which will otherwise succumb to lethal diseases like bud rot, ganoderma wilt or pests like rhinoceros beetle or red palm weevil.

Other technologies: AI is by no means the only way technology is revolutionizing agriculture. There are a host of other technologies too. Hydroponics, for instance, is a method of growing plants without soil, using mineral nutrient solutions in a water solvent. Sundrop, an Australia based company, has used this technology to put a sea water green house to grow vegetables anywhere in the world. 3D printing, also known as allied manufacturing, is now being applied in food production. Block chain, the distributed ledger technology behind Bitcoin, can be used to help fight food fraud. Nano technology has come in, driving a new revolution of precision agriculture. Nano encapsulated fertilizers today release nutrients in a slow sustained manner resulting in precise dosage to plants. Vertical Farming – the process of growing food in vertically stacked layers – is also catching up producing food in environments where suitable land is unavailable. The US based Aerofarms for instance is a pioneer in hi-tech, data – driven vertical farming and has shown that productivity can reach new heights hitherto unachieved. Netherlands too has witnessed an indoor growing boom thanks to technology with its green houses that occupy less than 1% of its farm land producing 35% of the country's vegetables. Per se, these technologies may not be applicable to the coconut sector. But technologies cannot be seen in isolation. Neither can a coconut sector be divorced from the agricultural sector viewed in a holistic perspective. For example, for finding coconut oil adulteration, a prototype can be developed for tracking and recording supply chain in block chain and checking its authenticity through a mobile application. The road ahead must be characterized by Right Place, Right Time and Right Product. The choice before the agricultural sector, its multifarious stakeholders and multilevel players is clear. ■