

Digital transformation in agriculture

powered by Artificial Intelligence and Machine Learning

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As the population increases and incomes rise, demand for food also increased. In a recent report published by the FAO it is expected that total demand for agricultural products in 2030 will be about 60% higher than today. More than 85% of this additional demand will be in the developing countries, as nearly all population growth will be there. Although there is systemic progress in the potential to increase production, there are many challenges that needs to be addressed such as availability of suitable arable land and productivity decline, availability of water required for irrigation, assessment of climate change impact on food production, prevention of damage to agriculture crops due to pests, and others. Although systemic progress has taken place to the boost the agricultural development digital transformation with the application of artificial intelligence and machine learning has become an imperative for the sustenance making many innovations possible in the field of agriculture. This paper highlights the digital transformation trends and various analytics use cases for digital agriculture highlighting the application of Artificial Intelligence/Machine Learning on the data collected with Internet of Things (IoT) Platform that can providesuitable acceleration to meet the global demand. The paper also highlights the new analyticslifecycle with the advent of IoT and the need to establish agriculture innovation, and excellence centers across the country designed for specific farmer needs.

Key words: Agriculture Innovation, AI/ML, Artificial Intelligence, Innovation, IoT, Machine Learning

TO achieve the required global food supply, investment in areas of digital transformation in agriculture is required. New technology is re-shaping the approach to agriculture and it can potentially deliver many benefits, and improved production. Digital transformation with adoption of emerging technologies has the potential to revolutionize agriculture by helping farmers work more precisely, efficiently and sustainably.

Artificial intelligence (AI) and machine learning (ML) nest under the largest doll of data science, whose purpose is to extract insights from data. Data science analyzes large amounts of data to deliver value and give businesses a competitive edge across all industries. In the growing world of big data, it is important to

have an effective data science strategy to help make informed business decisions. These fields have become more prominent, as the attempts to

meet the growing demand and find efficient ways to extract value from data at scale has increased. Using AI and ML to accomplish these goals is



Fig. 1. Artificial Intelligence and Machine Learning Capabilities

a natural outgrowth of the big data movement.

Data-driven insights with the application of AI and ML to improve decision-making and practices would play a big role in the increase agriculture produce while making the job more attractive to younger generations.

AI and ML driven technologies are emerging to help improve efficiency and to address challenges faced by the industry including, crop yield, soil health and crop resistance. From developing innovative sensors to agriculture bots-based service centers, to real time analytics for predictive maintenance and drone based intelligent crop/plantation surveillance, digital agriculture is poised to see the most significant transformation in the coming couple of decades.

There are many agriculture innovations on the applications of AI/ML providing immediate impact and contribute a big way for digital transformation in Agriculture. In this paper few AI/ML Opportunities are discussed.

DIGITAL TRANSFORMATION IN AGRICULTURE - AI/ML DRIVEN OPPORTUNITIES

Soil condition monitoring and sowing time assessment and prediction

Farmers often get sub-optimal yield due to either seeding during poor soil conditions or maintaining poor soil conditions throughout the lifecycle. Deployment of sensors that can monitor the soil and weather conditions can optimize their water usage, increase produce yield, produce high quality crops, reduce water resource degradation and save a lot of money. Intelligent monitoring of soil systems will help farmers understand the actual soil water condition and how much their crops need to use. Soil moisture sensors enable farmers to take informed irrigation decisions on when to irrigate and how much water has to be supplied to avoid low quality production. It will help them get answers to questions such as:

- When is the best time for irrigation.
- How do I know if enough water



Fig. 2. Areas of Digital Transformation that would be enabled using Artificial Intelligence and Machine Learning

has infiltrated the soil.

- What is the soil depth reached by irrigation water.
- Am I using too little water? Too much or, just right.
- How much water loss can i expect due to soil evaporation.
- Has the crop roots absorbed enough water, and
- During days of no irrigation, how much reserve will be available for my crop?

Integrating with the past cropping, yield and loss data, insights can be drawn on soil and crop conditions, and optimize the usage of factors of production such as seed, water, pesticide, etc.

Deployment of such sensors, analytics for IoT platforms powered by AI / ML for soil condition monitoring such as moisture, soil temperature, humidity and soil nutrient sensors provides the required capability for generation of intelligent decision. It also provides the opportunity to develop low cost all weather/conditions innovative sensor moisture, soil temperature, humidity and soil nutrient sensors stick for monitoring real time soil conditions for multiple regions using AI / ML technique. Detecting the impact of various type of cropping on the soil fertility, type of cropping advises and integrate it with the soil health card systems gives the ability to provide daily recommendations to farms such as sowing time, nitrogen application, and effluent irrigation. Drone analytics can be used to identify crop readiness identification and

agricultural product grading

Mechanization excellence in agriculture using AI/ML for predictive maintenance

The contribution of agricultural mechanization has been well recognized in enhancing the production together with irrigation, biological and chemical inputs of high yielding seed varieties, fertilizers, pesticides and mechanical energy. It has been brought out in many studies by NCAER that the gross income per hectare is more than 60% higher on tractor owning farms as compared to the bullock farms. The average net return from a tractor owning farm on per hectare basis was reported to be 150% plus that of a bullock owning farm.

Operating a successful, profitable and modern farm is a difficult venture, to say the least. Long hours of hard work and dozens of different skillsets are required of today's farmers, whether they be soil based, dairy producers, cattle raisers etc. Any unplanned downtime of farm equipment's such as tractors and tillers can significantly impact the productivity of the farm. Proper maintenance of the farm machineries not only increases the productivity but reduces the expenses needed to keep the farm running at peak efficiency, increases the utilization of the equipment and life of the equipment.

Emerging technology such as Internet of Things (IoT) has brought in the capability to connect to sensors, devices to the farm's

equipment that gets data about the operations, driver, land condition, and weather condition in real time. Application of AI and ML algorithms on the real time data can provide not only usage benchmarks vs yield, but predictive alerts on upcoming failures, anomalous condition using fault codes generated by the machine, vehicle behaviour during harsh weather conditions and driving methods to avoid frequent breakdown.

Smart irrigation providing right quantity of water, at the right place in the right season for right crop

Irrigation demands 70% of the world's freshwater withdrawals. Approximately 90% of freshwater is used for irrigation in India. Despite that, farmers often obtain sub-optimal yields from their crop due to improper irrigation management practices. Forecasting water usage requirements for lands using canal irrigation across type of crops, seasons and extent of irrigation land is extremely challenging specially the varied types of seasons and crops grown in the expanse of India. Suitable platform to collect the data about soil condition, crop, irrigation facility and supply points needs to be made available and advanced Machine Learning (including deep learning techniques such as Recurrent Neural Network, Stacked Neural Networks) techniques can be applied for accurate forecasting.

To get the most efficient water supply chain, the accurate forecasts needs to be coupled with smart operations of irrigation would lead to efficient water supply chain and avoid loss of water. Developing multi-variate predictive model for multi-pool multi-gate operations using AI and ML for optimization of gate operation in open water canal irrigation system would be an important area of innovation. It is also important to deploy innovative operation and maintenance applications for monitoring of motors that drive gate operations and build motor condition degradation, motor failure predictive models using AI and ML.

The optimized water supply chain

will ensure that farmers are able to get highest possible yield from their crop.

Improving Disease Detection& Crop Protection using AI/ML

Image processing using deep learning techniques has been proven to be effective tool for analysis such as facial recognition, object detection etc in other fields. Agriculture sector where the parameters like canopy, yield, quality of product were the important measures from the farmers' point of view, many times expert advice may not be available at the right time, affordable, and their services may consume time. Real Time Image processing can change the situation of getting the expert advice well within time and at affordable cost since image processing. There are many applications of image processing in agriculture field such as weed detection, crop / plant disease detection and fruit grading. Using deep learning capabilities accurate results can be obtained as compared to traditional methods. Application of image processing can improve decision making for vegetation measurement, irrigation, fruit sorting, etc.

Application of AI and ML (Deep Learning) requires development of database across the Nation, State, District and Village level. Central databases with collection of images of crop-wise disease and plant-wise disease across various stages of development and associated remedial measures would provide the necessary training data for application of AI and ML. Application of AI / ML technique to classify the images for the type of diseases can provide prediction of diseases and stage of disease when any images are uploaded into the system. This can be extended to drone analytics for crop lifecycle monitoring and yield assessment and damage to crops. Quantification of the damage that will provide the extent of impact. Application of deep learning would provide remedial measures for such disease as prescriptive analytics. With real time data, development of innovative application for real time

monitoring of pesticide spraying and mobile application to quantify / assess the need / actual spraying and impact monitoring can also be provided.

Modernizing agriculture cold storage and greenhouse infrastructure

Logistics including transportation, inventory management, warehousing, materials handling and packaging, and integration of information, is related to management of flow of goods between the point of origin and the point of consumption. With the growing Indian economy and changing business perspectives, the scope of the logistics industry has broadened from rudimentary transportation of goods to include end-to-end supply chain solutions including warehousing and express delivery. With the increase in minimum support prices covering almost all kinds of agriculture produce good storage and transportation facilities is becoming an imperative.

Post harvesting smart warehousing and cold storage provides the opportunity for better realization of prices to farmers. As per recent survey, India incurs post-harvest losses in fruits and vegetables worth 2 lakh crores/year due to lack of storage and processing facilities and approximately 10 million MT of food grain lost every year. Enabling technologies such as IoT provides innovative opportunity for monitoring fleet movement and modernize warehouse infrastructure. IoT based real time monitoring, analysis and early warnings using location, temperature, humidity, light, smoke / dust sensors with controllers for different condition and degradation alerts using real time streaming analytics for specific type of agriculture produce store can help prevent food stuffs and food grains from perishing or decaying.

Dawn of new digital agriculture era

Agriculture sector has seen series of transformations for production and crop management with mechanization, high yield seeds, resistant crop varieties, use of agrochemicals but digital agriculture

with the application of AI / ML would be the most transformative and disruptive of all of these. Modernization of agriculture with the usage of digital technologies will not only change how farmers farm but will fundamentally transform every part of the agri-business value chain.

To be able to do that agriculture sector needs to manage the new analytics lifecycle that would include collection of data, aggregation of the data, and application of analytics with AI/ML to deliver informed, actionable insights for farms / business/ research decisions and deploying it in real time as the use case maybe.

Moving from the current era of siloed research driven data collection and analysis, digital transformation should deploy solutions that are able to manage the above lifecycle pertaining to farmers issues or value chain needs at national, state, district, panchayat taluka or village level. All the solutions deployed should have the above capabilities with the deployment of analytics for IoT platform powered with robust AI / ML capabilities to develop innovative solutions, intellectual property for rural workforce, Conversational systems designed for farmers advise, and command centers that can provide 24*7 services to the agriculture community. Such platforms should be:

- **Diverse:** Support open connectivity to existing devices and new smart devices for open data, range of analytics including AI/ML capabilities both at the enterprise and edge, embracing and extending existing open source deployments, addressing the cross-domain business need of use cases that would have high sources of value.
- **Scalable:** For high data speed and volume, analytics, AI and ML quantity and the need of streaming analytics at the edge, structured, unstructured and image/video data and analytics, Speed to intelligence.
- **Trust:** Provide governance with integration with IoT platforms and device management systems, auditability, analytics administration for both central and distributed intelligence, edge device and data

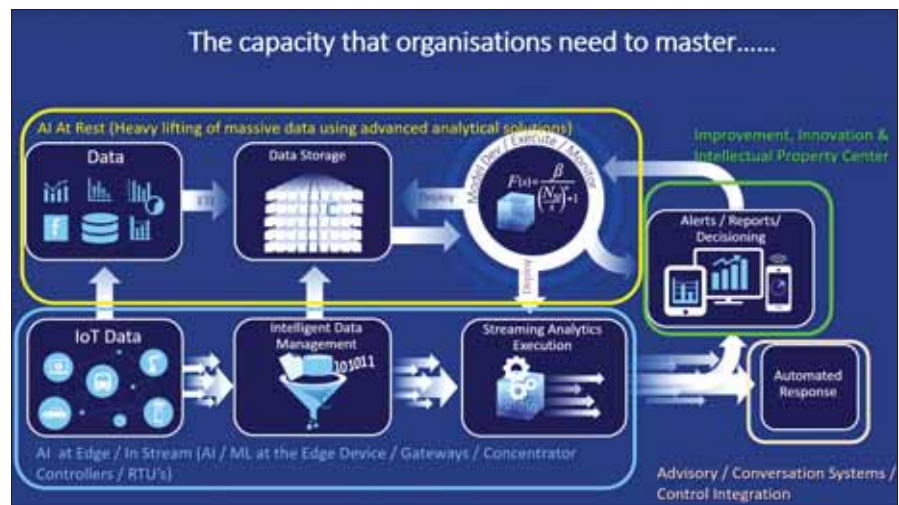


Fig. 3. Edge to Enterprise Analytics Platform Capability Architecture for Cross-domain agriculture centers and distributed intelligence

security and resiliency.

The ability to integrate with multiple systems, devices and applications is critical for the decisioning centers. As a part of innovation, the model development with the use of AI and ML will continue to happen at the cross-domain innovation centers but the deployment of such models would either be at the central big data platform or at the edge devices depending upon the low latency decisioning need of the use cases. The edge to enterprise platform should provide the flexibility of such deployments. Edge intelligence provides a method to optimize where the intelligence is located that would reduce dramatically the data transport requirements.

The streaming analytics engine should provide the scale for the deployment of AI / ML models for image and video classifications with real time integration to the images / video streams. The edge devices also need to take into consideration the need of deploying and processing large AI / ML components with support of GPU and other hardware accelerators. The need of real time insights at the national, state, district, and village level brings in the need of having good governance of the overall process of data collection, application of AI / ML and the deployment at the edge. This necessitates the need of integration with sensors, gateways, applications, image / video databases, IoT device

management systems and edge to enterprise analytics platform.

The capabilities of the edge to enterprise analytics platform and the effectiveness of AI and ML would provide the foundation to digital agriculture lead transformations.

Move from experimental approach to empirical evidence for precision farming and beyond

Sensor technologies, advanced communication systems and the power of real time analytics that can be deployed at the edge devices has brought in a fundamental shift in the data collection, analysis and advise. It has made possible collecting of data at granular level throughout the year (> than 60*24*7*365) that can enable research scientists develop solutions based on empirical evidence than experimental data. The edge to enterprise analytics can provide significant cases as discussed above such as predictive maintenance for intelligent farm equipment's, smart crop disease detection techniques; bench marking agriculture produce; crop yield prediction with accurate forecasting; and distributed intelligence (DI).

This would require an architecture that supports building layered intelligence at the national, state, district and village level. To capture the possibilities, agriculture workforce skills needs to be developed in the areas of:

- **Product and Service Innovation**

Using advance concepts of design

thinking, design sprints, software engineering and agile system design coming up with minimum viable products that can address agriculture value chain, farming and community need.

- **Modern Architecture**
API development across various sensors / devices / gateways that provide standard integration approach with localized / industry protocols.
- **Analytics Process Automation**
Detection and intelligent systems with model fine tuning that can anticipate new patterns with the huge amount data and automate the process of analysis of images and videos that can bring in huge productivity improvement as well.
- **Design of Innovation Centers**
Setting up innovation labs, hackathons for use case design and prototyping and mobile application development for farmers related agriculture production and improvement in the areas of factors of production.
- **Robotic Process Automation**
For improving services to farms through service centers such as early warnings for predictive maintenance before important cropping seasons and during the harvest seasons.
- **Manage Intellectual Property**
Enabling agriculture workforce to develop intellectual property

collaborating with industry players.

CONCLUSION

Digital transformation in agriculture is entering the next level of modernization. Edge to enterprise analytics platform for IoT and AI/ML are the two big levers of this modernization. In short, the more data is available from digital agriculture, the more business strategies, product designs, farmers approach, customer preferences and even agriculture organisation support structures will change. Using these levers, the degree of decisioning system shift, the type of innovation services and solutions that a farmer or the value chain can receive would bring in desired momentum to meet and sustain the global agriculture demand. An inspired, younger, urban-rural mix and transformed workforce will go a long way in making digital agriculture the foundation to sustenance.

Establishing AI and ML platforms at national, state, district and village level is extremely critical. Deployment of the AI/ML infrastructure in this paper would require large skilled workforce in this area. Therefore core teams of data scientists across the country focused in the domain of agriculture needs to be developed and deployed through and by the national / state and district offices. Large scale capacity building

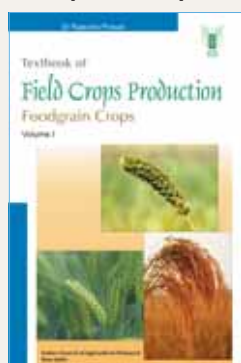
program for Artificial Intelligence and Machine Learning program should be made across leading agriculture universities, research institutions and extension centers. Ph. programs needs to be restructured with substitution of thesis work with innovation work on specific AI/ML application in any of the prioritized areas in agriculture through setting up of an incubation center for a duration 3-5-7 years. The incubation center should be built in collaboration of industry players and commercialization / funding / scholarship support from Government bodies. Academia and industry collaboration with central / state / district administration should be strengthened for fast realization of benefits in identified areas and test beds that can be executed, and ROI observed within periods of 8-12 months, 12-24 months and 24-36 months.

With more than 9 billion people predicted to populate the planet by 2050, digital transformation in agriculture with the application of artificial intelligence and machine learning is key to drive the growth in agriculture production and crop, plantation and livestock management.

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Textbook of Field Crops Production – Foodgrain Crops

(Volume I)



The first edition of Textbook of Field Crops Production was published in 2002 and there has been a heavy demand for the book. This book is now being brought out in two volumes. The chapters cover emerging trends in crop production such as System of Rice Intensification (SRI), export quality assurance in the production technology of commodities like Basmati rice, organic farming, resource conservation technologies, herbicide management etc. Good agronomic practices must judiciously inter-mix the applications of soil and plant sciences to produce food, feed, fuel, fibre, and of late nutraceuticals while ensuring sustainability of the system in as much possible environment and eco-friendly manner. The advent of hydroponics, precision farming, bio-sensors, fertigation, landscaping, application of ICT, GPS and GIS tools, micro-irrigation etc. is in the horizon. The textbook covers both the fundamentals of the subject and at the same time inspire and prepare both teachers and students for the emerging frontiers.

TECHNICAL SPECIFICATIONS

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