Research Article
Volume 10:7, 2021

Journal of Electrical and Electronic Systems

ISSN: 2332-0796 Open Access

Emerging Smart Technologies for Site-Specific Crop Management: Practices and Trends

Muhammad Irfan Mughal*

Department of Computer System Engineering, Sukkur IBA University, Sukkur, Pakistan

Abstract

Agricultural practices have fed humans for tens of thousands of years and various crops have been cultivated but the ever increasing world population demands more crop yields. Precision agriculture has given a new meaning to cultivating crops and livestock in farming. Site-specific crop management is a precision agriculture method, which utilizes differential management approach by monitoring and recording variability in crop fields. This approach is basically about applying the right farm input in right amount to right site at the right time. Sensors, Geo-spatial technologies and variable rate applications are the common static digital technologies employed in site-specific crop management, which are termed as traditional technologies in this work. Traditional technologies have enabled automation in crop management. In recent decades, smart technologies like artificial intelligence, internet of things and other smart technologies are greatly researched and employed in crop management for making it autonomous and intelligent. In this review, a study of traditional technologies' existing trends and practices in site-specific crop management is conducted. Different experimental setups, trends, advantages and drawbacks of emerging smart technologies are investigated. It was observed that AI and IoT are the leading smart technologies in site-specific crop management. Furthermore, challenges in adopting smart technologies are discussed. It was concluded that emerging smart technologies rely on smart data and specific frameworks are needed for smart data collection and sharing with other stakeholders of the agro value chain for improving food production and security.

Keywords: Precision agriculture • Site-specific crop management • Smart farming

Introduction

Site Specific Crop Management (SSCM) is a familiar term for the farmers as they understood it with their enriched cultivation experience that various parts of crop field require different farm inputs for increased yields. But this practice was totally depend on any individual farmer or region's knowledge about their local fields. Furthermore, manual labor was quite hard and restricted farmers to cultivate only small fields. Although, mechanical tools and vehicles were and still used in farming, farmers were not able to cultivate large fields comfortably. New paradigms were explored for improving these practices. Digital technologies like sensors, geo-spatial and variable rate technologies were developed. They quite rapidly merged with their mechanical counterparts and gave promising results. Nowadays, smart technologies are deployed with digital practices to further enhance the crop production and food security. Adoption of smart technologies led to better understanding of field variations. This new trend is making crop production easy to manage especially in remote settings. SSCM is implemented in three stages, first collecting data through sensors, secondly, data analysis which leads to appropriate decision making and finally applying this knowledge to improve crop management.

This approach is used to apply farm inputs like seeding, irrigation and fertilizers etc. differentially as per specific site requirement in the crop field. This improvement in decision making can increase crop yield and minimize environmental hazards. These variabilities are mapped to create distribution patterns in space or time [1]. These patterns are the basis for applying farm inputs (like seeding, irrigation and fertilizers) to specific site (in spatial variability) or during different growth stages (in temporal variability) of the crop. Authors have presented following contributions for understanding and adopting smart technologies in SSCM:

- Discussed existing trends and practices employed in SSCM.
- Explored emerging smart technologies and methods in SSCM published in recent research papers and articles.
- Highlighted challenges in adopting smart technologies in SSCM.
- It was concluded that smart technologies are emerging in every SSCM areas and new frameworks are needed to address these trends in crop management.

***Address to correspondence:** Dr Muhammad Irfan Mughal, Department of Computer System Engineering, Sukkur IBA University, Sukkur, Pakistan, Tel: 03352266019; E-mail: erfaanmughal@gmail.com*

Received: 26 August, 2021; **Accepted:** 09 September, 2021; **Published:** 16 September, 2021.

Materials and Methods

Assessing soil and plant variability across a cultivation field and during multiple seasons is the first step in implementing SSCM. Soil sampling is preformed to study trends in soil fertility and land leveling for irrigation across the crop field. A field is divided into a grid or management zones (grouping similar field areas hence require careful considerations) to collect sample. In former scenario, sampling is intense and feasible for small field whereas in latter scenario random samples are collected from different management zones, which is better for larger fields. Soil sample analysis results are used to develop an application map indicating differential needs of the whole field. This application map is used to manage variable needs of nutrients, water, weeds, pest and diseases in the crop field. Use of recent smart technologies in agriculture have greatly benefitted the farmers by providing timely information about crops from planning to post harvest. Mentions different old traditional, traditional digital and smart practices employed in SSCM.

In Section II, SSCM's existing trends and practices are elaborated, section III considers recent emerging trends in SSCM, section IV indicates the challenges in adopting smart technologies, and section V concludes with some future directions and recommendations in SSCM.

Existing trends and practices

Digital revolution provided immense opportunities to every field of life. Similarly, agriculture sector benefitted massively from it by employing digital technologies for improving food management and security. Many traditional digital agriculture practices in SSCM includes technologies like WSNs (Wireless Sensor Networks), VRT (Variable Rate Technology), RS (Remote Sensing) and GIS (Geographic Information System). These technologies are used for multiple decades and can be considered as traditional technologies in today's smart agro-world. Sensors are the basic tools required to implement these technologies.

A variety of sensors are available in market ranging from a simple in-situ temperature sensors to complex sensing systems. Soil sensors are considered as the most important sensors because they are used to monitor soil's chemical contents and this knowledge is used to apply the precise amount of fertilizers to optimize soil fertility for improved crop yield. SSCM can manage farming in a systematic approach by collecting data through sensors for weather, irrigation requirements, fertilizers etc. in real-time.

This data is analyzed and appropriate recommendations are provided to manage the land variability for improved crop yields as shown in Figure 1. The whole field is divided into small fields or zones and each small field is managed individually to optimally apply farm inputs [2].

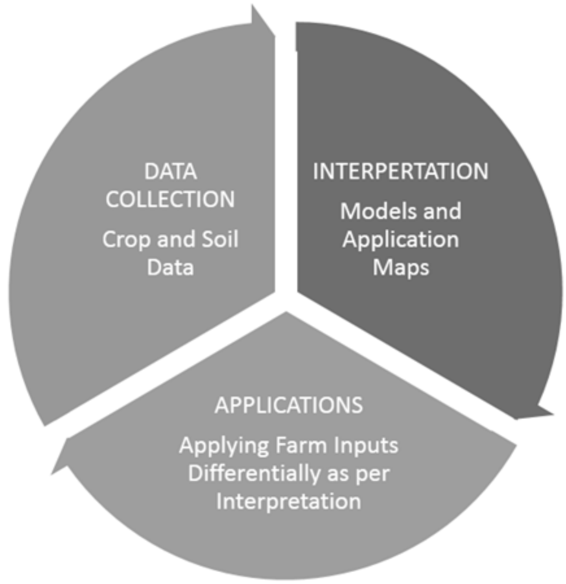

Figure 1 Site specific crop management cycle illustrating phases of data collection, interpretation and application.

Wireless sensor networks

Wireless sensors are the main enabler of SSCM as they provide the platform for monitoring and collecting information about crop management. Multiple wireless nodes are deployed across the field to sense soil nutrients, crop growth and irrigation needs for the specific sites or zones in the field. These sensors group together to form a Wireless Sensor Network (WSN) and its general architecture.

Sensed data is routed through the gateway to either local or remote user for further data processing. Nowadays, WSN technologies are quite developed and also economical for comfortable adoption in agriculture. Crop sensing systems deploy in-situ sensors, on-the-go sensors, aerial and satellite imagery to monitor soil and crops. In-situ sensor are implanted in the soil across the field, on-the-go sensors are deployed on unmanned or manned aerial or ground vehicles and imagery is acquired from drones or satellites for soil and crop's chemistry analysis. Soil sensors are the most common type used to monitor chemical levels, which in turn informs about the soil fertility of the field. These sensors are discussed in detail for real time soil monitoring (Figure 2). DDK Rathinam proposed a real time WSN based system crop monitoring system to measure water and diseases in the crop and forwarded this to the farmer and agricultural specialist's smartphone for immediate resolution of any detected issue by the system. In recent years, energy efficient WSNs, IoT based WSNs and UAV-WSN systems have gained importance. These trends are summarized in Table 1.

Remote sensing

Remotely sensed data about an object is interpreted to determine the required information for some specific application like determining crop growth from satellite images. Figure 2 shows a basic RS system. The concerned object emanates the energy incident on it through an intervening medium from an illuminating source at some specific frequency. This reflected energy is received by a sensor and is processed to identify its respective spectrum which in turn identifies the object's different properties.

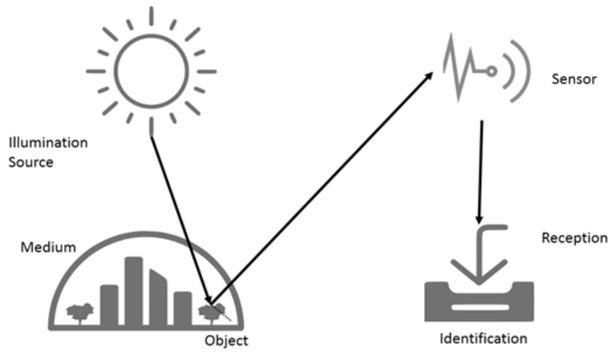

Figure 2. Remote Sensing System working through processing sensed reflected energy of object for object identification.

The spectrum analysis varies as per the properties of intervening medium and object, it may partially or completely reflect or absorb the incident energy (e.g. plain grounds reflectance is different from urban areas reflectance) so only some frequencies in spectrum offer transparency for remote sensing. Image represents the sensed data as analog or digital signals e.g. in satellite digital images, pixels represents the latitude and longitude coordinates of some specific geographic location. Furthermore, pixel size defines resolution when mapped to Earth. Mostly, a multilayered image is formed by collecting data from different sensors for every pixel for determining greater knowledge about specific site/s. A variety of imaging sensors including optical (conventional or digital cameras), multi-spectral (image is captured in usually 3 to 10 different bands), hyper-spectral (image is captured in more than 100 contiguous bands), LiDAR (light detection and ranging) and non-optical are used in RS. Acquired image data is digitally processed to remove distortion (noise) and then it is interpreted to recognize the object and its properties [3].

Recent Trends	Previous Work Weaknesses	Proposed Work	Technologies Employed
Energy Efficient Sensors	Inadequate battery life of sensor nodes, costly and very hard to replace	Energy harvesting(EH) based WSNs	WSNs, IoT, EH platform (Solar)
Aerial and ground platforms integration	Ineffective sensor data collection through aerial platforms	Optimized trajectories of UAVs and optimum network latency based data collection from in-situ sensors	WSNs, UAVs, Fog Computing, Cloud Computing
Low cost sensors and processing platforms	Costly wired communication and proprietary systems	Sensor data processed on Open source hardware and stored in IoT cloud for interpretations.	WSNs, IoT, Raspberry Pi

Table 1. Wireless sensor network trends.

Crop phenology is the occurrence of periodic events in the life cycle of a crop. These phenological changes describes crop growth duration, crop carbon cycle and other crop abilities. The phenology of crop monitoring is a current research topic in PA using satellite and UAV sensors. These sensor data are analyzed temporally and spatially to understand monitored crop changes at regional and global levels. Crop phenology monitoring can determine the reasons for low crop yield or crop diseases during one or multiple seasons of crop cultivation. LiDAR and digital cameras (RGB or multispectral) are commonly used. LiDAR sensors produce a point cloud in 3D and classifies points according to their physical properties like urban, vegetation, water, etc. Moreover, these point clouds can be merged with camera outputs to develop multilayered images providing more detailed field mapping for various purposes created multiple plots from the same crop cultivated in the field. These plots were individually processed to obtain average bare earth height from the LiDAR based Digital Terrain Model (DTM) of complete field and these results were used to estimate the crop height and density.

In SSCM context, it generally refers to use of UAVs or Satellites to detect and classify crops in the field. UAVs can capture better quality field images or point clouds to perform assigned tasks but cover only small fields well whereas satellites can cover large fields but its spatial resolution cannot accurately detect small scale field changes.

Results and Discussion

Satellite data can be easily acquired from free satellite sources like NASA earth observatory or ESA. Detected Climate change effects on wheat crop in North China Plain were detected using satellite data. Thermal infrared remote technique sensed salinity soil levels and determined the reduced transpiration in plants which led to low plant growth in Northwest China. RS data collected over a longer duration can be analyzed to determine new information about crops. The classified crops with an overall accuracy of 92.22% by applying Random Forest algorithm to seven year Landsat NDVI time series of Southeast Kansas, USA. Daughtry used Landsat-8 and WorldView-3 data of one year to differentiate crop residue from soil and estimated crop residue cover successfully.

UAV is an economical and easy to use as compared to satellites and can provide higher spatial resolutions because of its ability to fly at lower heights. Such high resolution images can provide better results for many SSCM applications like crop growth and disease management. Furthermore, it can employ multiple sensors to provide high spatial and temporal image analysis for determining crop and soil variability in the field. Vegetation parameters and payload limitations defines the applications of sensors in UAV. Commonly, visible light, multispectral and LiDAR sensors are used.

Visible light sensors are energy efficient, provides high resolution images and need simple image processing. It can capture images in bright sunlight and cloudy weather but is prone to camera distortion and needs post image processing for crop properties analysis accurately. These sensors help in creating high resolution 3D Models (Digital Surface Model or Digital Elevation Models) of photogrammetric technique by collecting multiple overlapping crop field images to build an orthophoto, which is geometrically corrected to give a uniform scale for analyzing vegetation parameters (like height or density) and yield predictions [4].

Multispectral sensors provides abundant information on many vegetation parameters as it uses multi-bands (5 to 12) as compared to visible light sensors. For instance, healthy crop can be determined by studying the specific bands reflections like chlorophyll absorbs visible radiation in red band but near infrared is reflected. Vegetation indices are developed from this spectral transformation of specific bands (2 or more) and are used for specific applications. NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) are commonly used to calculate crop growth stages and to differentiate among soil and vegetation respectively.

NDVI value ranges from 0 to 1 and is quite sensitive to vegetation cover but soil properties (like brightness, color) and atmospheric affects (like clouds) its performance and hence calibration is needed for accurate results. In a raw NDVI image taken using multispectral sensor mounted on a UAV was processed using histogram-based auto-adaptive filter for removing striping noise from the captured image. This noise is caused due to the UAV platform vibrations and it need to be removed for better vegetation studies.

EVI optimizes the NDVI vegetation signals using additional BLUE spectral band, which removes atmospheric distortion and hence improves results. A variant of multispectral is hyper-spectral sensor, which can process spectral reflections in hundreds of bands. UAVs and satellite images are useful for monitoring crop growth and diseases but early detection is difficult as mostly crop is already damaged due to late detection. It is helpful to mitigate further crop damage but in some crops damage can hardly be managed. IoT based UAVs are the recent trend in PA technologies and provides higher resolutions of few centimeters which greatly enhances its ability to understand vegetation parameters. Multiple sensors (like multispectral, hyper spectral, thermal, LIDAR) can be mounted on a single UAV, data link for communications and a ground station altogether formed an Unmanned Aerial System (UAS). UAS like sense fly Ag Drones have the ability to capture multiple VIs in just one flight.

Variable rate application

Conventional farming employs manual or machine work for uniform distribution of farm inputs (water, fertilizers, pesticides etc.) to cultivate the field. This approach is unable to manage field variability and consequently farm inputs are wasted. This mismanagement may also affect the yield and is uneconomical due to high farm input prices. These concerns can be solved by employing SSCM using VRA, which is a technique to apply farm inputs by manually or automatically observing and analyzing site requirements in the field. VRA is commonly used to manage crop seeding, irrigation and chemical applications. A cotton farmer in Louisiana used a grey tape on his rig front axle and distributed nitrogen only if the cotton heights was below the tape. This manual VRA scheme improved cotton yield and is called traditional VRA. Any farmer can use this approach through field observations or personal field experience to apply input like fertilizers or pesticides etc. Differentially in the field but is limited to farmer's decisions and constraints.

Sensor based VRA utilizes sensory data to perform any assigned task in real time. On the go sensors collects field data like sensing crop reflectance and processes this data to manage crop irrigation. Integration of Global Positioning Systems (GPS) with this scheme greatly benefits in geo-referencing of the field.
Another similar scheme is using map based VRA for SSCM. A prescription map is develop by processing sensed field data (or traditional analysis) and GPS for referencing specific sites, which guides the variable rate applicator to apply input differentially to specific sites as it moves across the field. GPS, soil moisture sensors, controllers and actuators are the basic tools for implementing VRA effectively in the field. Their common applications and variations in VRA. Researchers have discussed and developed many systems for improving VRA capabilities, for instance merging many new advance technologies to provide better control and automation in crop management. Machine learning is used to identify weeds in the field and variable rate spray is controlled by:

- Flow control
- Direct injection
- Pulse Width Modulation (PWM)
- Variable nozzle

Flow control method, system pressure is changed to achieve variable rate spray whereas in direct injection, main chemical injection in solvent is managed to achieve required concentration and spray rate is kept constant but mixing introduces delays in the system (Table 2). PWM signal controls the solenoid valve for variable rate spraying and is quite efficient whereas variable nozzle internal structure is driven by the system pressure to manage the variable rate spray. In a vision based spraying system using PWM signaling driven by machine vision algorithm was developed and was able to work efficiently in real time by spraying chemicals as per plant leaves density [5].

Common Tools	Variations	Applications
GPS	Differential GPS (DGPS), Real Time Kinematic (RTK)	Geo-referencing and tracking
Soil moisture sensors	Volumetric(measures water content) and tensiometric (measures water tension)	Monitoring soil moisture variability
Controllers	Computers and micro-controllers	Applying water, chemicals, etc. as per requirement or processed sensory data.
Actuators	Stepper motors, linear, Air springs	Automatically operating valves, gates, etc.

Table 2. Trends in variable rate application.

Satellite navigation

Satellite navigation plays a very important role in location information and vehicle guidance in SSCM. GPS is commonly used to serve these purposes. GPS aids to develop accurate farm maps and allows farmers to precisely mark specific sites for monitoring crops. Positioning errors are a common place in GPS i.e. calculating the GPS receiver coordinate may vary from few to tens of meters which could fail the concept of specificity in SSCM. Differential GPS (DGPS) and Real Time Kinematic (RTK) are common correction methods for positioning errors with later being more real time efficient as former needs time consuming post processing. In DGPS, received coordinates are compared with an additional pre-coordinated earth base station positioning error corrections and can provide an accuracy of few centimeters but is expensive as compared to traditional GPS. RTK provides accuracy of 2 centimeters by measuring the carrier's phase as well as the signal content using a single reference or rover station. Agricultural vehicle guidance is crucial to develop autonomous systems and is carried using GPS receivers which guides the vehicle as per pre-developed maps or in real time. In row crops, tractors must be aligned accurately with crop rows for efficient agricultural activities. A low cost solution to improved tractor orientation is the use of tractor kinematic model along with GPS receiver. Row guidance control systems employing GPS along with a mechanical row detector using an angular sensor to calculate row deviations and feeding it to control system for improved GPS guidance of the tractor.

Geographic information systems

Geographic Information Systems (GIS) application in agriculture started in 1970s and since then it has been researched and developed a lot. It consists of geographic data, storage, data analysis, management and user interface. It can analyze enormous geospatial data and overlay analysis provides a lot of insight into it and makes it a great decision support tool. RS, GPS and GIS are converged to form a 3S technology where RS tools provide field images, GPS positions and navigates the field resources and GIS is responsible for information management of acquired field data. Agricultural resources are hard to manage but 3S abilities can map these complex resources together and their features (spatial and temporal) can be depicted in multiple levels. In china, adoption of 3S technology in information management system led to improve the local agricultural science park management practices by aiding to the decision making process of park's management committee. This digitization and automation provides a comfortable way of managing and sustaining agricultural resources. GIS has a major role in information management system of agricultural resources and is an essential tool for information statistics. These statistics can be used to develop agricultural climatic zoning reports for planning new crops and preventing climatic calamities due to global warming. Expert Systems (ES) are also now integrated with GIS and provides intelligent field spatial analysis. ES in decision support systems provide valuable insights into the cropping land selection by managing land features as per growers requirements and processing land data from various sources. Mobile GIS is used to monitor fields and supports the decision making process with the comfort of portability. Nowadays, its considered as in built due to extensive mobile applications in almost every aspect of SSCM.

Emerging smart technologies

Smart technologies have influenced SSCM enormously and are securing a permanent place among common crop management technologies. These trends can become sustainable solutions for fulfilling increasing food demand and security challenges. In SSCM, smart technologies can improve production, use of resources and environment. Following is a brief account of various emerging smart technologies' trends and practices in recent years.

Artificial Intelligence (AI) or machines with intelligence (i.e. similar to human intelligence) have revolutionized today's industries and even life of an individual. Autonomous manufacturing plants to smart phones, small or large AI applications are everywhere. AI has a lot to offer in agricultural sector from smart decision support systems to autonomous agricultural vehicles but is still at infancy stage.

AI based autonomous systems have the potential to improve traditional agricultural practices as well as SSCM. Integration of AI tools like machine learning, machine vision and autonomous vehicles have been researched in context of SSCM to develop new advance technological trends in SSCM.

Artificial neural networks are computational algorithm used in machine learning, a neuron is the basic building block of this network and acts as a simple computational device with intense interconnectivity. Input data to a neuron is assigned some data relative weight, which defines its input intensity. Output data of neuron is the algebraic sum of all the weight input data. ANN based systems are composed of multiple neurons which group together to form neural networks having input layer, hidden layer and output layer. Hidden layer function is to continuously adjust the input data weights till desired results are achieved. Weight adjustment can be feed forward (input to hidden layer) or recurrent (output to hidden layer).

Oil palm crop is strongly affected by soil quality and climate change like heavy rainfalls and farmers may face up to 50%reduction in yield if mentioned parameters are unsuitable. ANN based controllers were able to manage water requirements of palm fields but better prediction analysis are still needed. ANN back propagation algorithm was optimized to recognize pattern in agricultural data and better predictions were made about soil quality and weather. The R-CNN as described in are commonly used for weed detections in SSCM to separate them from actual crop.

AI based UAVs are also making their way into SSCM and scholars have discussed their merger in recent years for making UAVs autonomous. This is achieved through smart route planning and machine vision and is helpful in spraying and mapping of the crop field.

Internet of agricultural things

Immense data requirements have made it inevitable to connect every device and system with the Internet for sharing data autonomously for developing smart systems. The use IoT based sensing systems in SSCM have turned farming practices smart, more interactive and autonomous. IoT based sensing systems are given different terms like Internet of Underground Things (IoUT) and Internet of Agricultural Things being adapted in SSCM. IoUT is primarily concerned with the real time soil monitoring, wireless communications and interconnections among different components of the underlying system.

Underground things are wireless sensors with water and weatherproof shielding for effective sensing. Base stations forward sensed data to cloud server whereas Mobile sinks are installed in tractors, UAVs or irrigation systems.

The IoAT model is data collected over time is analyzed to acquired new knowledge and this is applied to develop dynamic models which support decision making more interactive and smart.

Proprietary or open source IoT platform can be used for IoAT. For instance Cisco has developed a comprehensive IoT based platforms, which provides a broad range of solutions and services to industries from manufacturing to utilities sector. The open source system must fulfill some criteria to be termed as an IoAT system. This system will have the same basic components as some simple automated system has i.e. it will monitor, analyze and will act accordingly for the assigned task. The main difference lies in the magnitude of spatial or temporal data measured (may include metadata), which DSS may analyze using complex multiple decision algorithms and forward to actuating system to fulfill desired task. The actuating system may perform more than just simple commands like optimizing energy consumption, dynamic networking options, standbys, etc. Such complex system fulfilling multiple requirements smartly will qualify to be IoT based SSCM methods. New trends in IoAT is the use of cognitive IoT technologies, which employs AI based IoT systems integrated with cognitive computing platforms to make SSCM methods even more iterative and more intelligent.

Data is the single most important resource in any management system to administer processes in an effective manner. In SSCM, huge data is generated by the hundreds or thousands of sensors deployed in the crop fields. Analysis of this enormous resource for making effective decisions is the most difficult part of the management system. Big data is an advance technology which offers the ability to process and analyze enormous, diverse and complex data for optimum decision making. As per DATA FAIRport, data should be Findable, Accessible, Interoperable and Reusable. This in turn gives rise to importance of metadata i.e. data about data. Data value chain, which includes steps of data collection to data-driven decisions manages farm data to provide real-time decisions and intelligence to SSCM practices. Decision support systems or Farm Information or management systems can even predict natural events (like heavy rainfall, climate change, etc.) with great accuracy. Agricultural intelligent decision system employs big data analysis technology to provide instant expert analysis at farmers' doorsteps. Such a knowledge based system for wheat crop was able to guide farmer for decisions in almost every aspect of farming (from crop planning to harvest). Big data analytics predicted with 77.09% accuracy about a good or bad crop yield using machine learning techniques. Big data is acting as a data source for many new technologies like AI, IoT, Industry 4.0, etc. and is becoming a prerequisite for smart technologies.

Block chain is a cryptographically linked records (blocks) list (chain). These blocks contains a hashed key, timestamp and transaction data, copies of these chains are distributed among network nodes. This distributed behavior makes it resistant to changes and needs a complex decryption process to insert new blocks into the chain. In SSCM, Block chain is used in agricultural supply chain and farm monitoring. Block chain is primarily used for secure money transactions without the need for a trusted third party but this technology can be applied for data security and availability needed for any purpose. In SSCM, it is being researched for data security, service platforms, management information systems, etc. Private Block chain access control algorithms were used to develop a secure protocol for securing farm network and information systems. While implementing agricultural products traceability i.e. from farm to fork, IoT sensors data security is achieved by employing. Ethereum block chain technology to design smart contracts and reliable data transmissions. This system is scalable and is flexible to add new service components and even virtual currency for adding value to itself. In, authors have presented a use case, which can be integrated with existing block chain systems to serve as an improved block chain for managing food supplies in post COVID-19 era.

Agricultural cyber physical system

Cyber Physical Systems (CPS) have enabled the seamless integration of physical world (sensors and actuators) and cyber world (data and control center). Its basic equation is a sum of computation, communication and control techniques. It allows the integration of computations and physical world responses among heterogenic systems. Its real time response is based on the global reference time for in-time communications among cyber and physical systems. It has shown great progress in many industrial sectors like medicine, energy, chemicals, etc. This could also be applied to PA methods or SSCM. As ACPS, consists of crop sensors send data to a control center through (using sink nodes) Internet, where data is processed (for making intelligent decisions) and commands are sent for actuators to perform needed actions in the crop field. UAV, UGV, GIS and AI based ACPS are also researched and used in agriculture for providing application flexibility to farmers as per their farm needs. As the name suggests, all cyber components can be connected to agricultural components. An AI based ACPS is discussed in .from architecture to applications in different PA methods.

Agricultural robots

Most advance technologies are playing their roles to develop agricultural sector in order to resolve the issue of growing food demands. Robotics is an advance form of communication, control and automation. It enables to automate many tasks and processes to reduce human effort and saves time. Intelligent machines are not only helpful but also ensures safety of the environment in which it is deployed. Agricultural robots are used to perform a variety of tasks like seeding, planting, harvesting, irrigation needs and many other farming tasks. Different designs include end effectors, grippers, manipulators etc. End effectors are the application specific devices attached to the end of a robotic arm like a sprayer, cutter or a claw for grabbing or picking. The manipulators guides the end effector to exact place or point in space for performing its assigned task. Unmanned ground vehicles (UGVs) and UAVs are also used as manipulators for providing more movement flexibility in the rough terrains. UGVs are mostly line following robots (LFR) and move on their preset paths or paths are planned before every activity in the farm. UAVs based applications have been discussed in many research papers and many diverse UAV base PA tools or solutions are developed. In UAV based sensing, harvesting, spraying and mapping for different farm needs are discussed in detail. Different types of UAV platforms like fixed-wing and rotary wing UAVs are used for these mentioned applications.

Agriculture sector is one of the biggest beneficiary of industrial development and revolutions. It has lead agriculture from manual to machined farming and now from automation to autonomous plus intelligent farming.

Agriculture 4.0 is the fusion of new advance technologies like AI, IoT, Big Data, Block chain, ACPS and Agricultural robots. As this technology will gradually make its way to larger farms in the future, it will enable on-the-go intelligent applications of farm inputs. Farm management systems will become more autonomous and will be able to learn and act according to their farm experiences. This will give rise to autonomous farming through autonomous navigation, accurate detecting and intelligent actions of farming systems.

Challenges in adopting smart technologies

Mechanical to smart technological practices in agriculture increased land cultivations as well as the profits for the farmers. In mechanical era, uncontrolled farm inputs led to high amounts of farm inputs like water, fertilizers and pesticides which does not necessarily produce higher yield. Furthermore, it may decrease the average seasonal yield and also create imbalance in the market prices of farm chemicals due to unnecessary higher demand. Smart technologies in agriculture commits to provide better food security and crop management but adopting smart practices have its own challenges like cost, availability, energy requirements and skilled manpower.

The primary concern of any business is the cost to profit ratio to ensure its sustainability. Cost associated with adopting smart technologies in agriculture must ensure profits to individual farmers as well as to all the stakeholders of the food supply chain. Research efforts have been made to minimize cost of adopting smart technologies. In, a low cost framework is developed using super-capacitors and is functional for 24 months. Anna Triantafyllou have proposed a decision model for modeling the cost feasibility for PA monitoring system by calculating the deployment requirements.

The efficiency that smart technologies provide can be turned into profits only if these technologies are easily available or deliverable to farmers. Smart tools and systems operations and management in the crop fields calls for innovative agribusiness modes and enterprises. This can create opportunities for service oriented startups for providing better service availability to farmers at economical costs. These issues still need to be address deeply as they effect the adoption of smart technologies in agriculture.

Energy requirements is yet another challenge which can disrupt uninterruptable operations of sensing system of smart technologies in SSCM. Immense research is conducted in making these systems energy efficient like enhanced battery life, energy saving nodes and using renewable energy sources. But all of the propose solutions have their own operational constraints primarily depending upon geological location, size and local weather conditions of crop fields. Research and discussions are needed to account for ecological effects of energy sources on agriculture and environment. Renewable energy sources are mostly recommended in most research projects. In, an off-grid renewable framework for farms is proposed. Low cost system prototype design was calculated and validated the theoretical design. It was concluded that proposed design can provide sufficient power for farm operations independent of the utility power grid. Energy smart SSCM can prove to be the central pillar for making smart SSCM sustainable as they can be implemented with or without utility power grid.

Conclusion

The impact of smart technologies is massive on crop management and it has revolutionized it. Summarizes this impact by presenting smart technologies employed in major SSCM areas. IoT and AI are the leading smart technologies in this regard. The significance of smart IoT sensors is increasing in smart farming practices and various IoT platforms are developed for this purpose. New farming frameworks especially considering smart farming services as a separate sector are needed. A service provider can utilize provided farm data (by farmers or other users) for determining feasible solutions for improving crop yield and management.

This has made crop management quite easy to handle specially from remote locations and these technologies are the future of farming. The cognitive aspects of smart technologies are yet to be explored in SSCM. Cognitive technologies can play an important role in further optimizing the crop management by utilizing smart data. This could enable systems to make humanly decisions and can extrapolate results on their own.

References

1. Ivanov, Stepan, Bhargava K, and Donnelly W. "Precision farming: Sensor analytics." IEEE 30 (2015): 76-80.
2. Salima, Yousfi, Peira JFM, Ablanque PVM. "Remote Sensing Data: Useful Way for the Precision Agriculture." IEEE (2019).
3. Marios, Sophocleous, Georgiou J. "Precision agriculture: Challenges in sensors and electronics for real-time soil and plant monitoring." IEEE (2017).
4. Liu, Ye, Xiaoyuan M, Shu L, and Hancke GP, et al. "From Industry 4.0 to Agriculture 4.0: Current status, enabling technologies, and research challenges." IEEE 17 (2020): 4322-4334.
5. Rathinam, D Devi Kala, Surendran D, Shilpa A, and Grace AS, et al. "Modern agriculture using wireless sensor network (wsn)." IEEE (2019).

How to cite this article: Mughal Irfan Muhammad. "Emerging Smart Technologies for Site-Specific Crop Management: Practices and Trends ." *J Electr Electron Syst* 10 (2021) : 31674