Blockchain-Based Infrastructure for Precision Agriculture

A. Packialatha, S. Vijitha, A. Sangeetha, and K. Seetha Lakshmi

1 Introduction

In agriculture, distributed ledgers and smart contracts, which are part of blockchain technology, have the potential to eliminate counterfeits in agri-food production chains, resulting in healthy and balanced products being made available in the market, establishing trust between industry leaders, and empowering a better quality of life on a global scale [12]. Consumer demand for digital services suited to their unique needs develops as the human population grows (Fig. 1). According to Sharma et al. [18], blockchain technology can be used for agriculture and farm management software to improvise farm financial performance and meet the growing demand for food.

The agriculture industry must undergo technological change in order to:

- Offer higher quality foods technology solutions to meet evolving customer expectations, while also satisfying the need of a growing population.
- Reduce your carbon impact with the help of eco-friendly agriculture strategies.
- Lower the cost of agriculture's supply chain.

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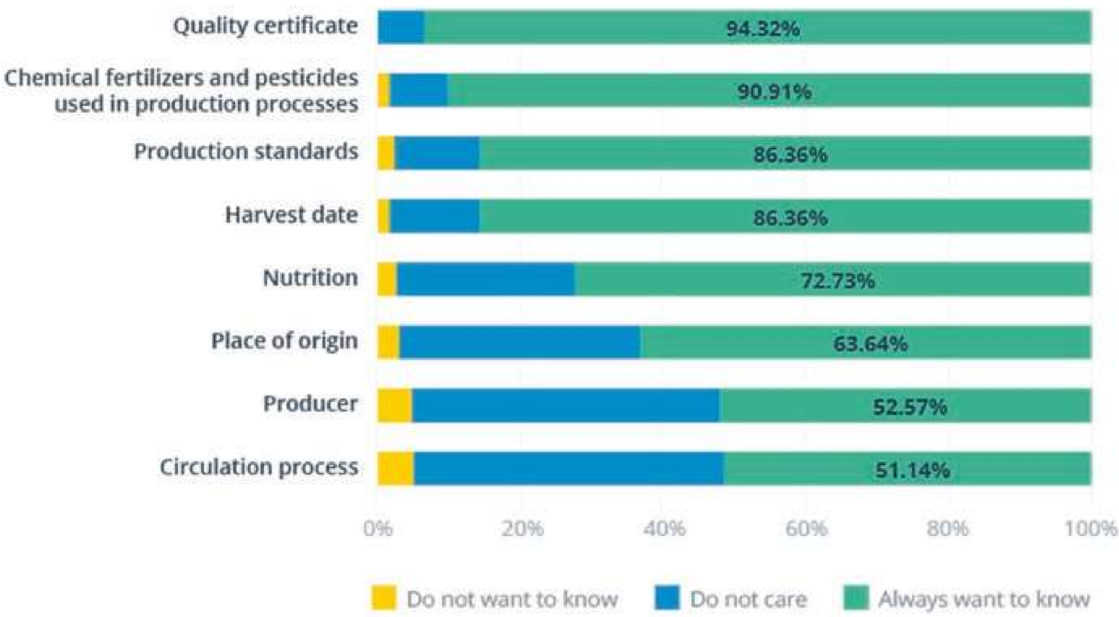

Fig. 1 Demand for information about food

Fig. 2 Precision agriculture system

- Strictly cohere to sanitary and phytosanitary guidelines.
- Help small farms, individual farmers, and food producers maintain profitable agricultural and agribusiness operations and make more money.

Sensing with IoT [17], agribusiness organisations, topographical intelligence systems, and yield managing software package, as well as data management, in-season decision-making, and grid specimen technologies, are allowing agricultural businesses to improve their nourishment creation and stock chain organisation. Consumption of food is amplified with new issues, such as fake goods, which represent a threat to nutrition stock systems on several stages. Due to inefficiency as well as lack of transparency, agronomists and customers are at a drawback [16]. Finally, blockchain farming and distributed ledger technology (DLT) have the potential to raise the efficacy, clarity, and assurance in the cultivated source chain (Fig. 2). Blockchain for cultivated source chain can authorise entire marketplace participants by constructing reliable connections.

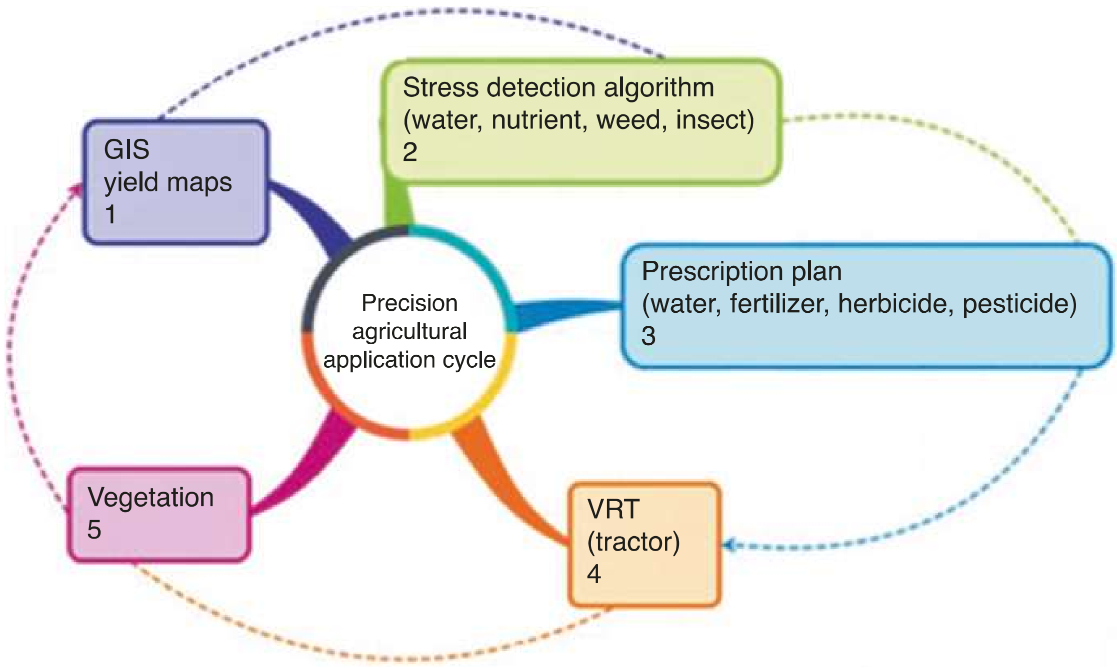

Fig. 3 Application cycle of precision agriculture

Precision agriculture is defined as "the use of cutting-edge resource technology to access and examine multiple resources with big dimensional and progressive determination for decision-making and crop production operations." Figure 3 shows a precision agricultural cycle. GIS, or geographic information system; VRT, or variable rate technology, is a technology used in agriculture to increase output [11] and sustainability. It is becoming increasingly crucial to use data and information to raise production and sustainability. Data and communiqué technology improvise the efficacy for collecting the resources, stowage, scrutiny, and convention in agriculture [25]. It permits agrarian experts and cultivating societies to simply attain up-to-date date and make better decisions in their daily farming operations [7].

Sensors are mounted on specialised stands for practice in technical research, breeding, prototype growth, ecological observing, and accuracy cultivation, enabling for proper sensor functioning to capture phenotypical characteristics of floras or other biotic substances. Implementing blockchain technology in agriculture presents a number of challenges, as well as potential solutions:

Cultivation source chain supervision is an added difficulty than other source chains, while agronomic output is affected by uncontrollable factors, including weather, pests, and illnesses. Financial transactions are slower and human labour is frequently required in the agricultural supply chain due to the lack of traceability. Additionally, imitations might appear at any point in the source chain, posing a threat to all shareholders in the organisation, as well as governments and consumers.

1.1 Why Is Using Blockchain Technology a Better Approach for Precision Agriculture?

The quality of the seed, the crop growth, and even the path a plant takes after leaving the farm can all be tracked using blockchain technology. With the help of this information, supply chains might be more transparent and problems involving unethical and illegal production could be diminished.

2 Precision Farming Components

2.1 Internet of Things (IoT)

The connectivity of IoT interacts with items equipped with sensors. It allows physical objects to be detected and operated from afar, bridging the gap between the actual creation and virtual systems. Pumps, sheds, tractors, weather stations, and computers are just a few of the equipment that may be remotely supervised and measured in physical period. Smart wearables and linked gadgets, as well as automated machinery and autonomous cars, have all been made possible by the Internet of Things [8]. Despite its rarity, precision agriculture is one of the most essential IoT applications. These new technology advancements to improve harvests might save lives as our globe approaches a food catastrophe. Natural circumstances must be predicted and responded to as fast as possible in order for farming to be efficient and profitable [8]. In Fig. 4, the Internet of Things is driving this application, which is a new approach in farming. Precision agriculture and data collecting quality may both benefit from IoT technology. The Internet of Things is used to collect data from sensors that detect various factors such as soil moisture and humidity and to remotely monitor them via developed mobile applications to take decisions [2].

Merits and Demerits

Improvising flexibility of processes stands the major benefits of engaging IoT in cultivation [2]. Agronomists can quickly acknowledge to any substantial variation in meteorological conditions, moistness, air value, or the health of any yield or soil in the field using instantaneous monitoring and prediction systems. It reduces the amount of human labour and labour and helps save time and effort. Lack of infrastructure is one of the most significant challenges that farmers encounter when integrating IoT in agriculture [9]. Farmers can appreciate the IoT technique, but they are unable to obtain assistance from it as there is no proper network structure. Farms are located in rural places with limited access to the Internet. Unemployment has increased. Concerns regarding privacy have intensified in recent years [19].

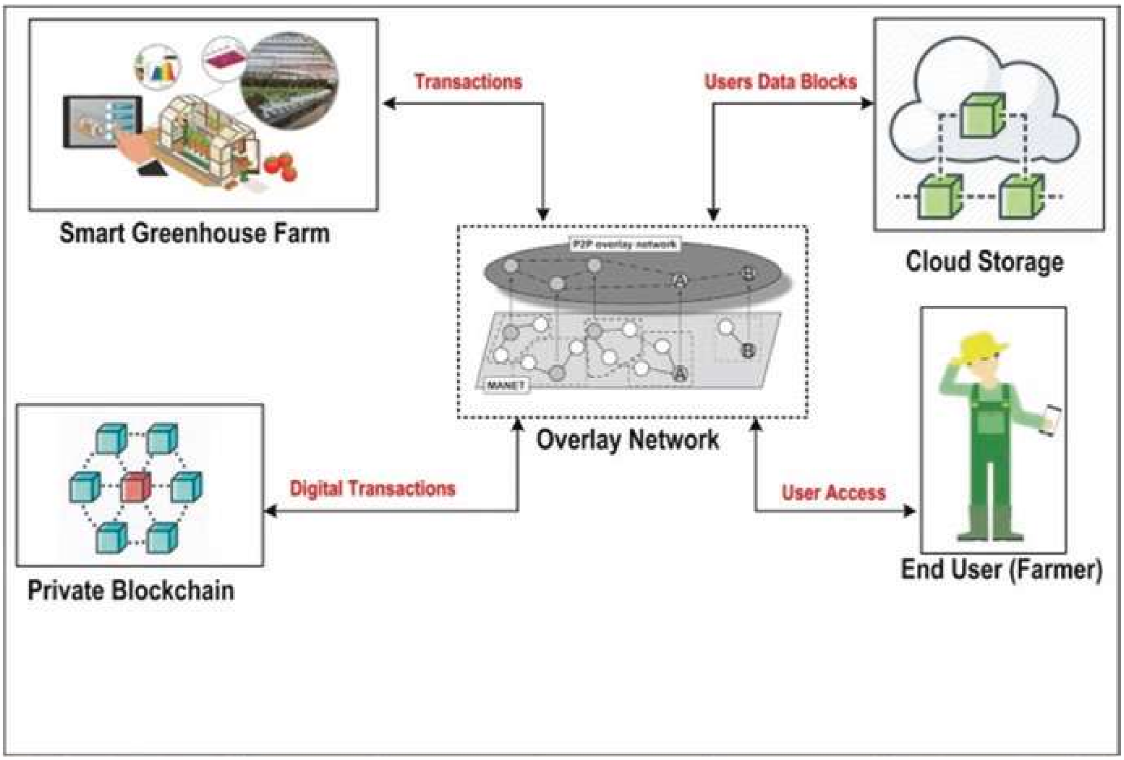

Fig. 4 Internet of Things (IoT)

2.2 *Grid Specimen*

The method of gathering tiny samples at similar intervals throughout a certain area is known as grid specimen. Soil samples are collected in a grid system at consistently spaced locations. Grid dimensions vary from one to five acres, with minor grids producing the best results. For each one-acre grid cell, collect at least five subsamples [13]. For grid cells among 2.5 and 5 acres, gather 8–10 subsamples. In Fig. 5, soil sampling aids precision agricultural producers in developing management zones and prescription maps, improving the accuracy of rate and placement of essential inputs (primarily fertilisers and lime to adjust pH [1]). When collecting soil samples, producers and managers frequently employ Grid or Zone Sampling methodologies. Grid sampling indicates the distribution of nutrients over a field. We acquire a better knowledge of the nutrients available by collecting more soil samples from a field [13]. We can be sure that the fertiliser expenditures are being used wisely if we know what nutrients are accessible. In areas with high nutrient levels, a grid specimen reduces fertiliser overapplication. Grid sampling enables fertiliser augmentation in areas where nutrient levels are low. A fertiliser programme with grid soil sampling and variable rate application of lime, gypsum, and fertilisers gains control and security [20].

Merits and Demerits

Measures the nutrients left in your field after harvesting. It shows you which nutrients in a field's soil are insufficient or abundant [1]. Assists in establishing the most

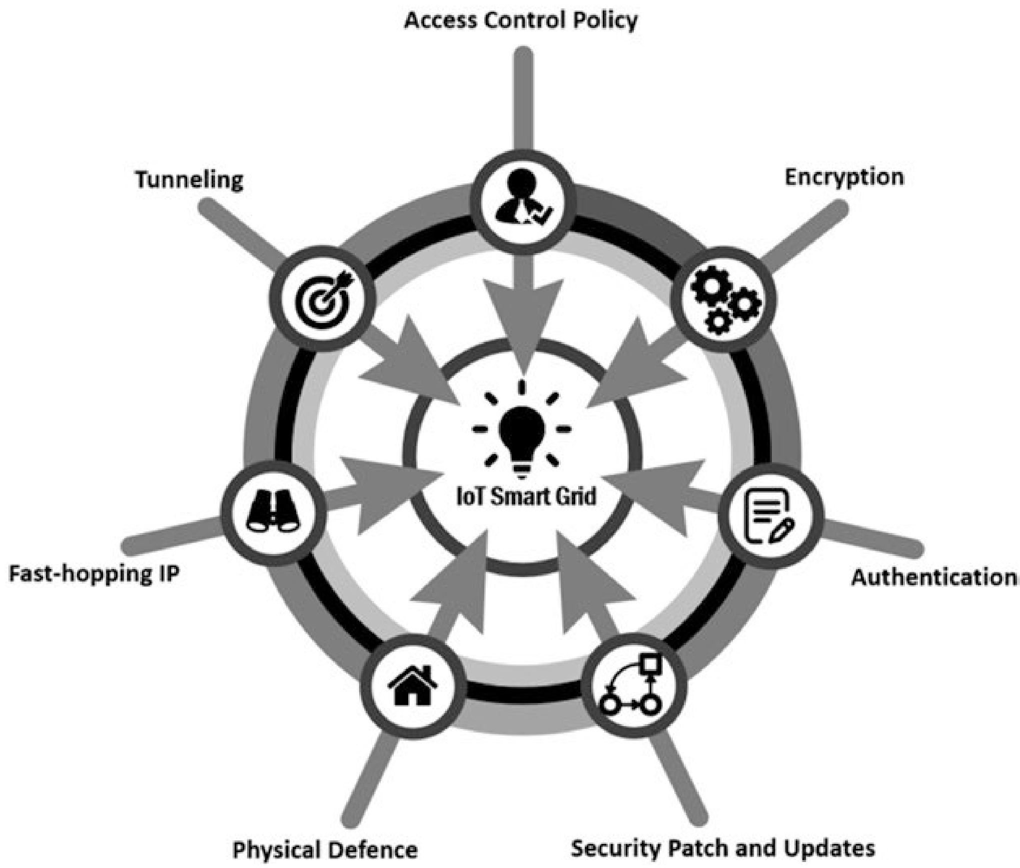

Fig. 5 Grid specimen

effective fertiliser method for growing or maintaining production the next year. Grids are appealing because they are simple to use and give better spatial data than whole-field soil sample [13]. Grid sampling has a number of drawbacks, the first of which is an improved chance of influence. If the bulk of grid specimen fall on a single soil type, for example, the grid miniature might diminish the underlying variety in the ground [20]. Grid sampling can be inefficient as well.

2.3 Topographical Information System (TIS)

In agriculture, TIS is all about assessing the land, plotting field data on a map, and putting that data to good use. Precision farming, which is based on TIS, allows agronomists to make informed choices and speculate in order to maximise the value of each acre, while reducing ecological effect [5]. Satellites, aircraft, drones, and sensors, to mention a few devices, are used in geospatial technology in agriculture. These technologies are utilised to make images and correlate to graphs and resources [5].

As a consequence (Fig. 6), a map with information is obtained about crop location and health, geography, soil type, fertiliser, and other factors. A topographical

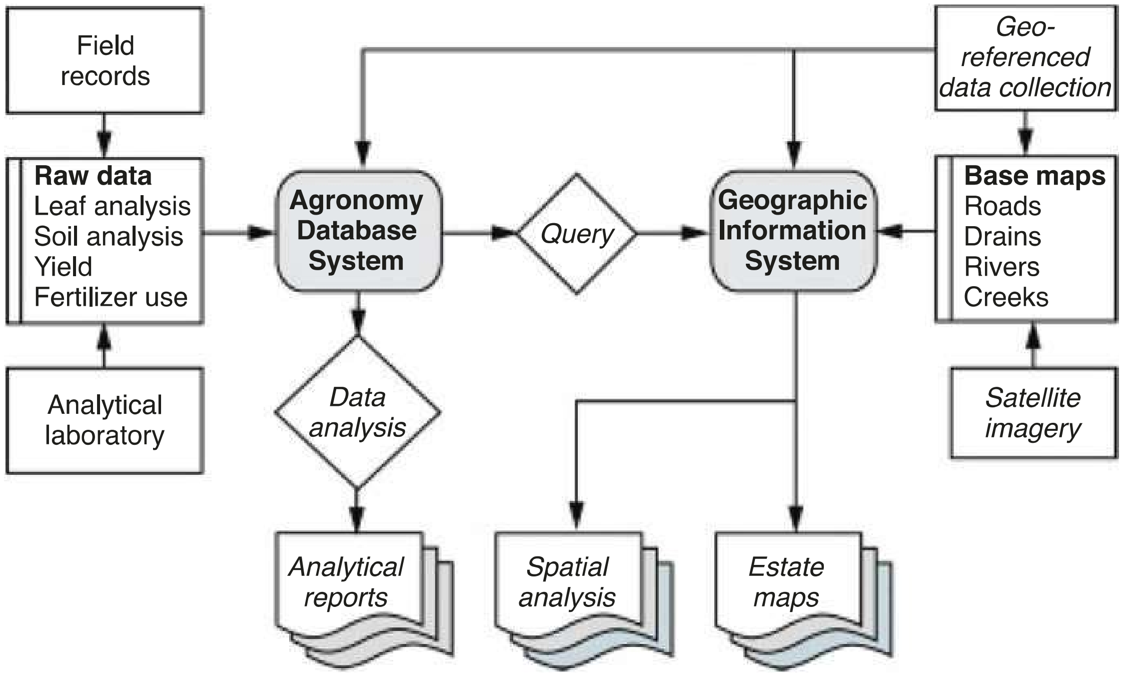

Fig. 6 Topographical information system (TIS)

information system (TIS) is a tool for collecting and analysing geographic data to aid in agricultural development. In Li, S., TIS can analyse soil data and determine which yields should be planted and how to maintain soil nutrition current so that plants get the greatest benefit. TIS in agriculture allows for better land resource management, which leads to increased production and lower costs for farmers.

Merits and Demerits

It has the ability to improve organisational cohesion. TIS would therefore combine software, technology, and resources in order to collect, analyse, accomplish, and display the entire forms of spatially connected information. TIS would also allow users to examine, query, analyse, visualise, and understand the resources in a number of formats, such as earths, maps, graphs, and collected information, to show connections, trends, and patterns. The goal of a Topological data System is to help people by answering their questions and rectify issues by analysing data in a fashion that is easy to understand and distribute [5]. TIS technology is frequently regarded as high-cost software. It also necessitates a significant quantity of data for various purposes, and the more data supplied, the better. When property agents interpret the TIS chart or the technologist's plan around the TIS useful outlines, TIS layers may result in expensive blunders [5]. There might be difficulties in starting or continuing attempts to fully integrate the TIS, but there could also be considerable benefits to look forward to.

2.4 In-Season Decision-Making

Farmers routinely make management decisions that affect their financial line, from hybrid selection to planter changes. The need of competent decision-making rises when margins shrink owing to low crop prices. Farmers must utilise all of the tools at their disposal to make the best judgments possible in every aspect of their operation in order to be successful [19]. Growers making educated decisions during the growing season rather than at the end of the year is the next frontier for precision agriculture. In Fig. 7, farmers' decision-making is ongoing throughout the growing season as they observe what is going on in their fields. That is why it is critical that maps and information are available on in-cab displays, cell phones, and tablets throughout the season [15]. Farmers do not make choices alone, which is why it is crucial to consult with reliable experts.

Merits and Demerits
Recognise that every decision you make for your crop has a monetary worth and an environmental impact as the first step towards confident decision-making. Then, using today's high precision technology, link precise data points to construct a solid foundation of facts to back up those conclusions [19]. It is critical to employ the correct precision agriculture technologies to lay a foundation of reliable data since poor data cannot lead to excellent decisions. Reliability, availability, and usability are the three key components that underpin agronomic decision-making [19]. Because approaches are continuously being refined, it is vital to get expert advice before making any costly decisions. It should be regarded as a long-term investment because the initial capital expenses are likely to be significant. Gathering enough data to fully implement the technology might take several years [15].

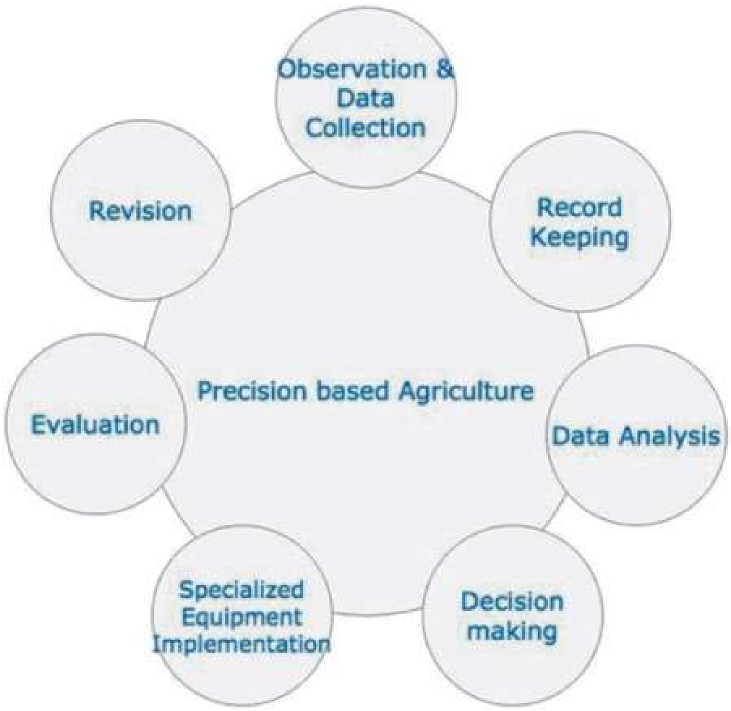

Fig. 7 In-season decision-making

2.5 Sensor Technology in Precision Agriculture

In precision agriculture [22], sensor technologies are utilised for yield mapping and prediction, soil sensing, fertiliser and pesticide application, irrigation management, and other applications. Sensors are commonly employed in precision agriculture to determine accurate targets and crop demands so that locally variable chemical dosages may be applied. Agriculture sensors are sensors used in smart agriculture. These sensors give data that allows agronomists to analyse and improve their yields by responding to environmental modifications. The agriculture business uses these sensors in meteorological stations, drones, and robots.

GPS satellite signals are employed by position sensors [21] to identify latitude, longitude, and altitude to within a few feet, which helps agronomists to analyse and enhance yields, and also to familiarise with altering ecological situations in precision agriculture. At least three satellites are essential to triangulate a location. Precision agriculture is strongly reliant on pinpoint accuracy. GPS integrated circuits, such as the NJR NJG1157PCD-TE1, are used to locate the detectors [4]. In Fig. 8, optical detectors use light to detect soil quality. The detector monitors distinct incidences of light reflectivity in the near-infrared, mid-infrared, and polarised light ranges. Vehicles, airy devices such as drones, and even satellites can be outfitted with sensors. Only two examples of variables that can be combined and managed are ophthalmic sensor data on soil reflectance and plant colour. Optical sensors may be used to assess clay, organic matter, and soil moisture levels.

Electrochemical sensors provide critical data for precision agriculture, such as soil pH and nutrient levels. In Wachowiak et al. [23], sensor electrodes are used to detect certain ions in the soil. Soil chemical data is now gathered, analysed, and mapped using detectors mounted on specially manufactured "sleds." Mechanical sensors are used to assess soil compaction, often known as "mechanical resistance." The detectors employ a probe that goes into the soil and records resistive forces using load cells or strain gauges. On large tractors, a same sort of technology is handled to predict the dragging needs for ground-engaging equipment. Tensiometers,

Fig. 8 Fundamental components of optical sensors (hundreds of photodetectors and photodiodes)

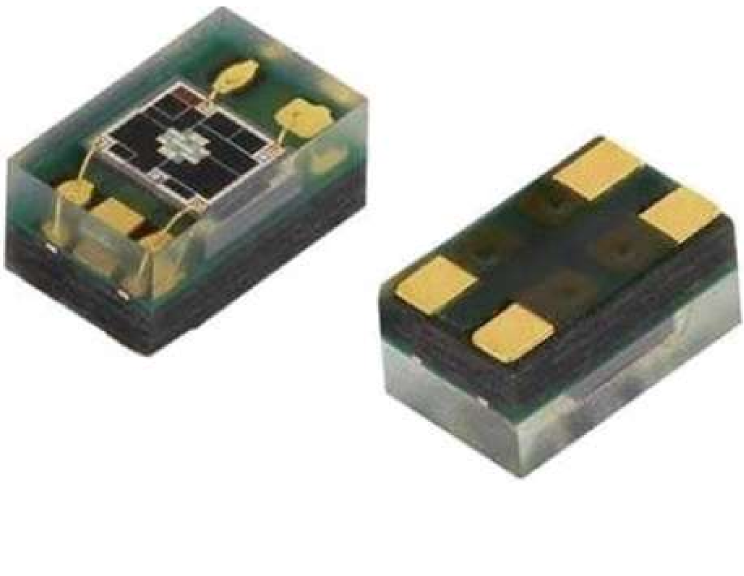

Fig. 9 Honeywell force sensor

such as the Honeywell FSG15N1A, are highly useful for irrigation since they measure the force produced by the roots in water absorption (Fig. 9).

Airflow. The air permeability of the soil is measured using sensors. Measurements might be made at certain places or while moving. The targeted outcome is the burden necessary to force a predefined quantity of air obsessed by the ground at a particular depth. Compaction, structure, type of the soil, and moisture level all provide unique distinguishing characteristics in the soil. Agronomic meteorological conditions are self-sufficient equipment strategically positioned across agricultural areas. In Wahabzada et al. [24], these stations are equipped with a range of sensors tailored to the crops and climate of the area. Air warmth, ground warmth at several intensities, rainstorm, leaf moisture, chlorophyll, humidity, dew point warmth, wind control, relative dampness, sun radiation, and atmospheric pressure are all monitored and recorded at predefined intervals. At specified intervals, this data is gathered and wirelessly transferred to a central data recorder. Because of their mobility and low cost, meteorological conditions are alluring to farmhouses of all dimensions. Sensing technologies produce actionable data that may be analysed and deployed as needed to boost agricultural productivity, while reducing environmental impact. Here are a few examples of how this data is used in precision farming.

Harvest Monitoring and Analysing methodology are installed on yield harvesting vehicles such as syndicates and corn gleaner. Crop mass yield is calculated using period, remoteness, or global position, all of which are sustained and taped to beyond 30 cm. Yield Mapping makes use of dimensional synchronised information from harvesting equipment’s GPS sensors. Yield maps are made by putting yield monitoring data and locations together. Weed Mapping currently builds maps based on operator input and interpretation, which are then quickly tagged with a GPS retriever and information jack. Slang incidences can be compared to harvest atlases, fertiliser maps, and spray maps, to name a few. As visual recognition technologies advance, manual input will be swapped with computerised, graphic devices fitted on working equipment.

Benefits from Sensor Technology

Sensor integration has the potential to boost farm output, save expenses, and enhance working conditions. Precision farming results in healthier cattle, more sustainable

Fig. 10 Weather monitoring solution and agriculture factors

farming operations, and more efficient production, in addition to enhanced performance. Sensor technologies provide secure data collecting, as well as a committed group is dedicated to better weather monitoring and other agricultural factors included in the following Fig. 10.

2.6 Data Management in Precision Agriculture

Farmers can also benefit from data by allowing them to investigate how various modifications to procedures, equipment, or other variables may affect profitability. Precision agriculture (PA) [6] service providers use agricultural data to generate suggestions for particular fields and give information about them. The key to making data valuable to a farm is putting it in a spot where it can be utilised to create information (i.e. "actioned"). In Fulton et al. [3], the data's worth will be maximised if it can be shared with trusted advisers and others who can evaluate it and produce recommendations and fresh insights into the farm operation. Farmers can also benefit from data by allowing them to investigate how various modifications to procedures, equipment, or other variables may affect profitability.

Precision agriculture (PA) service providers use agricultural data to generate suggestions for particular fields and give information about them. They use analytical tools to analyse farm data layers and deliver field suggestions, production estimates, soil moisture status, harvestability predictions, and other insights [10]. Figure 1 depicts the process a farm goes through when submitting data to an agriculture technology provider (ATP), which analyses the data and provides it to the farm for decision-making purposes. Figure 11 shows how vital it is to explicitly describe a data management plan in order to make the data valuable.

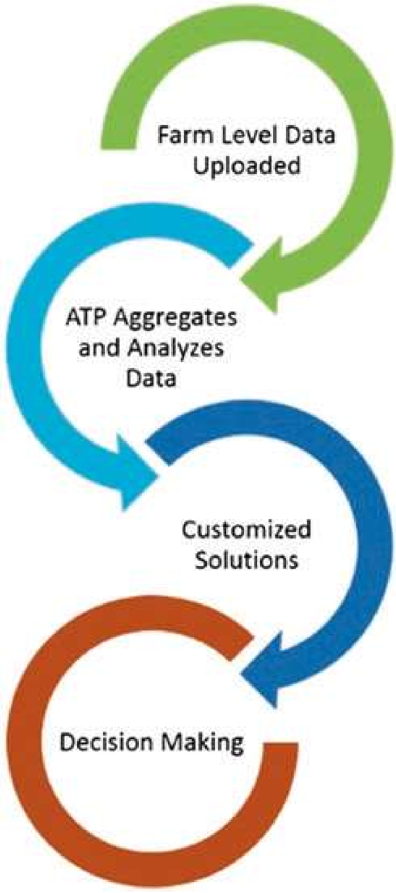

Fig. 11 Flow of data to provide information for farm decisions

The Big Data Flow
A farmer will use ground and equipment sensors, drones, and other devices to upload agricultural and personal data. Agricultural Technology Provider (ATP) will compile farmer data, mix it with other relevant data, and evaluate it using algorithms. Based on the data obtained, the ATP then provides the farmer with a personalised solution or advice. The farmer may then make agronomic, economic, and farm management decisions on their farm based on the ATP's suggestions.

Digital Agriculture
Today, digital agriculture is advancing as the sector creates services and technology that enable wireless data exchanges and data analyses. In Moreira [14], the expansion of precision agricultural tactics, prescriptive agriculture, and the trendy issue of big data and how it may enhance the agriculture industry are all part of the digital agriculture concept. Precision agricultural technology will help farmers, retailers, and custom applicators to improve nutrient management in terms of location, timing, and development of new data layers for assessing performance, which is a common thread running through this process. Most significantly, these geographical data layers will guide new policies that include allowances for sustainability and environmental nutrient management.

Data Sharing
As organisations and consultants provide PA services and the usage of digital technology on the farm, the ability to easily communicate farm data is becoming more crucial. If a clear method for storing and organising data has not been specified in a digital strategy, sharing agricultural data might be problematic. There are various methods for exchanging data effectively; here are two to explore as part of your farm's digital strategy:

1. Develop a system for sharing files both on and off the farm so that farm data may be utilised to capture fresh insights and learnings.
2. Store data in an easy-to-copy and/or share format with trustworthy advisers and PA services.

Data Storage
The correct storage and preservation of data is an important aspect of efficiently utilising data. To guarantee that there is a backup that can be retrieved in any circumstance, data should be saved in both on-farm and off-farm storage locations (i.e. "in the cloud"). In Kountios et al. [10], Cloud solutions should be password-protected and use any available cyber security features, while on-farm data storage should be kept in a closed, fireproof safe. At the very least, organise data by year, then crop, field, or farm, as applicable to the business. This will make it easier for you to find what you are looking for. Keep an original copy of data on-farm and off-farm so that you have a backup.

The "raw" data acquired by the in-cab display or gadget on agricultural machinery is referred to as an original copy. (Data that has been translated – for example, by uploading it to a farm management software platform – is no longer considered raw.) Having a backup of the original copy allows you to return to this data file at any time. Make sure data is accessible from a convenient location (the cloud, or a phone, tablet, or desktop computer, etc.). If you are utilising offline tools, be sure they will automatically sync whenever you have access to the Internet.

- Use safe passwords to protect data and never disclose it without authorisation.
- Create a method for digitising any data that was collected or written by hand.

Potential Benefits of Sharing Data and Storage Include
- Making better use of data acquired more rapidly
- Ensuring that judgments are based on a single source of data to avoid misunderstandings or incorrect interpretations
- Reducing the amount of redundant data collected
- Generating fresh insights
- Having access to data so you can double-check your findings (i.e. confirm results)
- Using greater datasets, scientists and researchers may conduct high-quality studies that have never been done before, leading to breakthrough discoveries for agriculture and the public benefit

2.7 *Precision Methods Used in Agriculture*

Precision methods (Table 1), the process of detecting, measuring, and reacting to numerous inter- and intra-field variability inputs, are at the heart of the farm management concept known as farming.

- Reduction in cultivation costs brought on by site-specific crop management techniques
- Enhanced input production efficiency as a result of site-specific input management

Table 1 Comparison between all components in precision agriculture

Internet of Things (IOT)	Grid sampling	Topographical information system (TIS)	In-season decision-making	Sensor technology	Data management
The performance of the workforce and the effectiveness of equipment may all be tracked using sensor data	Using grid sampling to take more soil samples from a field	It involves examining the land, displaying field data on a map, and using that data to make decisions	Making decisions in relation to selecting the right crop	Key data needed for precision agriculture is provided by electrochemical sensors: pH and amounts of soil nutrients	It is employed to create efficient technology to process the enormous amounts of data produced by precision farming production and study
IoT helps to regulate agricultural methods	Understanding the nutrients that are available is improved	Five key components are hardware, software, data, people, and methods	The result depends on environmental and soil factors	Specific ions in the soil are detected by sensor electrodes to function	It assists them in examining the potential effects of various adjustments to procedures, tools, or other elements on profitability
Drones, IoT systems for smart farming, and connected weather stations can all be used to collect this data	Identifying the variety of nutrient concentrations across a specific area is the goal of this method	Used to lower costs and improve functional performance	The level of crop appropriateness will be provided by the suitability analysis, and the user can then make a decision with that information	Enhanced sensitivity during data collection, nearly lossless transmission, and ongoing, real-time analysis	Farm data is used by service providers to create recommendations for and provide information about specific fields

- Reduced application of nutrients, particularly nitrogen fertiliser, reduces nitrate in groundwater and nitrous oxide in the atmosphere. Reduced soil and environmental pollution
- Chemicals are reduced using variable rate application technology.
- Decreased irrigation water application, which reduces nutrient levels and deep percolations
- Reducing water body erosion, runoff, and sedimentation

3 Results and Discussion

A topographical information system (TIS) is a tool for collecting and analysing geographic data (in Fig. 12) to aid in agricultural development. TIS can analyse soil data and determine which yields should be planted and how to maintain soil nutrition current so that plants get the greatest benefit. TIS in agriculture allows for better land resource management, which leads to increased production and cheaper costs for farmers.

In Sensor technology in Precision Agriculture, GPS satellite signals are employed by position sensors to identify latitude, longitude, and altitude (Fig. 13) to within a few feet, which helps agronomists to analyse and enhance yields and also familiarise with altering ecological situations in precision agriculture.

Fig. 12 TIS tool – collecting and analysing geographic data

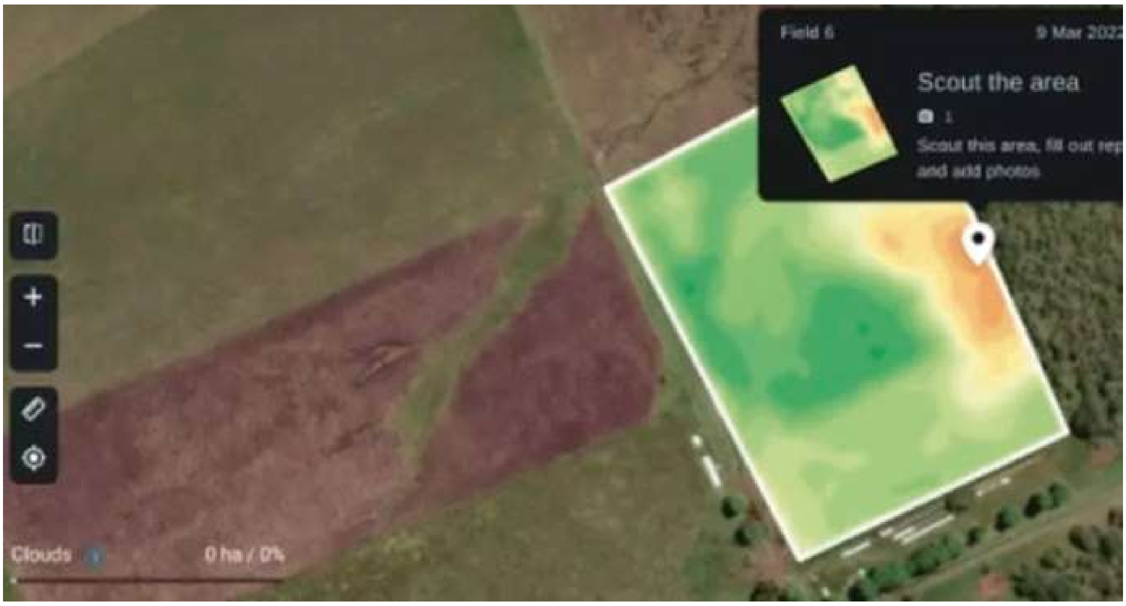

Fig. 13 Sensor technology in PA, GPS satellite to identify and alter ecological situations in precision agriculture

4 Conclusion

Precision agriculture has expanded to satisfy rising global food demand by utilising technology which is easier and less expensive to gather and use data, adjust to altering ecological circumstances, and make the maximum efficient use of resources. Smaller farms may now profit from these technologies as well, thanks to features incorporated into smart phones, related software, and smaller-sized gear. Furthermore, these technologies are helping to solve problems that are not limited to farms, such as pollution, global warming, and conservation.

Increased use of autonomous farm vehicles, as well as upgraded cellular data communication and collecting from keener, minor Remotely Piloted Aircraft are expected to be among the next precision agricultural breakthroughs. These lesser vehicles can track the position of agricultural apparatus as well as crop and soil conditions, allowing farmers to optimise machine maintenance and repair. Industrial manufacturing process advances will stay to invent their methods into agriculture.

References

1. Ackerson, J. P. (2018). *Soil sampling guidelines*. https://www.extension.purdue.edu/extmedia/AY/AY-368-w.pdf
2. Ahmed, N., De, D., & Hussain, I. (2018). Internet of Things (IoT) for smart precision agriculture and farming in rural areas. *IEEE Internet of Things Journal, 5*(6), 4890–4899.
3. Fulton, J., Port, K., Lindsey, L., Shearer, S., Darr, M., & Luck, J. (2017). *Digital agriculture tools to support soybean production: Final report to the united soybean board* (5).

4. Hassan, S. H., Van Ginkel, S. W., Hussein, M. A., Abskharon, R., & Oh, S.-E. (2016). Toxicity assessment using different bioassays and microbial biosensors. *Environment International, 92*, 106–118.
5. Intellias. (2022). *7 Ways how GIS in agriculture eliminates guesswork*. https://intellias.com/gis-in-agriculture/
6. Jasse, E. P., Bazzi, C. L., De Souza, E. G., Schenatto, K., & Agnoll, R. D. (2017). Plataforma Para Gerenciamen to De Dados Agrícolas. In Congresso Brasileiro De Engenharia Agrícola (Conbea). *The importance of agricultural engineering for food security* (pp. 1–6). ISBN 978-85-64681-13-2.
7. Kaddu, S., & Haumba, E. N. (2016). Promoting ICT based agricultural knowledge management for increased production by smallholder rural farmers in Uganda: A case of Communication and Information Technology for Agriculture and Rural Development (CITARD), Butaleja. In *Proceedings of the 22nd Standing Conference of Eastern, Central and Southern Africa Library and Information Associations (SCECSAL XXII)*, Butaleja, 243–252.
8. Karar, M. E., Alotaibi, F., Al-Rasheed, A., & Reyad, O. (2020). A pilot study of smart agricultural irrigation using unmanned aerial vehicles and IoT-based cloud system. *International Journal of Information Sciences Letters*, 1–11. https://doi.org/10.18576/isl/100115
9. Karar, M. E., Al-Rasheed, M., Al-Rasheed, A., & Reyad, O. (2020). IoT and neural network-based water pumping control system for smart irrigation. *Information Sciences Letters, 9*(2), 107–112.
10. Kountios, G., Ragkos, A., Bournaris, T., Papadavid, G., & Michailidis, A. (2018). Educational needs and perceptions of the sustainability of precision agriculture: Survey evidence from Greece. *Precision Agriculture, 19*(3), 537–554.
11. Lesser, A. (2018). *Big data and big agriculture*. Technical Report Analyst. https://gigaom.com/report/big-data-and-big-agriculture/. Last accessed November 23, 2018.
12. Lin, Y. P., Petway, J., Anthony, J., Mukhtar, H., Liao, S. W., Chou, C. F., & Ho, Y. F. (2017). Blockchain: The evolutionary next step for ICT E-agriculture. *Environments, 4*(3), 50.
13. Lukowska, A., Tomaszuk, P., Dzierzek, K., & Magnuszewski, L. (2019). Soil sampling mobile platform for Agriculture 4.0. In *2019 20th International Carpathian Control Conference (ICCC)* (pp. 1–4). IEEE. https://doi.org/10.1109/CarpathianCC.2019.8765937
14. Moreira, W. K. O. (2019). *Computational module for delineating limestone application maps from soil chemical attributes*.
15. Nicoleta, T., Stavros, S., & Manos, R. (2019). Data-driven decision making in precision agriculture: The rise of big data in agricultural systems. *Journal of Agricultural & Food Information, 20*(4), 344–380. https://doi.org/10.1080/10496505.2019.1638264
16. Preethi, K. (2017). *Blockchains don't scale. Not today, at least. But there's hope* [Online]. Available: https://hackernoon.com/blockchainsdont-scale-nottoday-at-least-but-there-s-hope-2cb43946551a. Accessed May 18, 2019.
17. Sam, M. (2018). *Blockchain in agriculture: 10 possible use cases* [Online]. Available: https://www.disruptordaily.com/blockchain-use-casesagriculture/. Accessed May 18, 2019.
18. Sharma, P. K., Chen, M. Y., & Park, J. H. (2017). A software defined fog node based distributed blockchain cloud architecture for IoT. *IEEE Access, 6*, 115–124.
19. Swindoll, C., & Ag Leader precision agronomist. (2018). *The rise of decision agriculture*. https://www.futurefarming.com/smart-farming/tools-data/the-rise-of-decision-agriculture
20. Velayutham, Y., Abu Bakar, N. A., Hassan, N. H., & Samy, G. N. (2021). IoT security for smart grid environment: Issues and solutions. *Jordanian Journal of Computers and Information Technology, 7*(1), 13–24.
21. Verrelst, J., Camps-Valls, G., Muñoz-Marí, J., Rivera, J. P., Veroustraete, F., Clevers, J. G., & Moreno, J. (2015). Optical remote sensing and the retrieval of terrestrial vegetation bio-geophysical properties – A review. *ISPRS Journal of Photogrammetry and Remote Sensing, 108*, 273–290. https://doi.org/10.1016/j.isprsjprs.2015.05.005

22. Virlet, N., Sabermanesh, K., Sadeghi-Tehran, P., & Hawkesford, M. J. (2016). Field Scanalyzer: An automated robotic field phenotyping platform for detailed crop monitoring. *Functional Plant Biology, 44*(1), 143–153.
23. Wachowiak, M., Walters, D., Kovacs, J., Wachowiak-Smolkov, R., & James, A. (2017). Visual analytics and remote sensing imagery to support community based research for precision agriculture in emerging areas. *Computers and Electronics in Agriculture, 143*, 149–164. https://doi.org/10.1016/j.compag.2017.09.035
24. Wahabzada, M., Paulus, S., Kersting, K., & Mahlein, A.-K. (2015). Automated interpretation of 3D laser scanned point clouds for plant organ segmentation. *BMC Bioinformatics, 16*(1), 248.
25. Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Opinion: Smart farming is key to developing sustainable agriculture. *Proceedings of the National Academy of Sciences of the United States of America, 114*, 6148–6150. https://doi.org/10.1073/pnas.1707462114