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Revolutionizing Agriculture: The Impact of Big Data

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Abstract :- In this era where every aspect of our day-to-day life is gadget-oriented, there is a huge volume of data that has been emanating from various digital sources. Today there are millions of data sources that generate data at a very rapid rate. Data analytics uses analytic techniques to examine data, thus obtaining and find out information like hidden patterns. The agriculture industry has witnessed a remarkable transformation in recent years, thanks to the integration of Big Data and advanced technologies such as machine learning (ML) and Internet of Things (IoT). Big Data analytics has opened up new possibilities for optimizing farming practices, increasing yields, and ensuring food security. This paper will explore how Big Data has revolutionized agriculture and provided some applications. Big Data contribute to making timely recommendations to farmers with regard to smart agricultural techniques. One purpose of current research is to get a better knowledge of the present state of Big Data processing in Agriculture and even to uncover underlying challenges that need to be addressed.

Index Terms:- Big Data, Data Analytics, smart agriculture, Machine Learning (ML), IoT

1) Introduction :-

Agriculture is the backbone of any nation's economy as well as the global economy.

Because it is regarded as one of the oldest vocations known to mankind. In some places like India, majority of rural residents depend on agriculture for their livelihood. Agriculture supplies our food, energy, and medicine and many more things to mankind.

At present time, the agriculture sector is facing several challenges such as climate change, increasing population, increasing labor shortages, land and water constraints, increasing urbanization, environmental degradation etc. With the global population projected to exceed 9 billion by 2050, it will be critical to optimize agricultural production and food supply chains to more efficiently produce and deliver food, fiber and fuel to meet growing [1]. So these big challenges can be dealt with by adopting latest technologies such as Internet of things, cloud computing, GPS technology, satellites, drones, robots, and artificial intelligence. These technologies are transforming agriculture and generating massive volumes of data, known as big data. Big data is critical to help

agriculture meet the challenges. It is new digital revolution to agriculture after green revolution. Big data helps to get information about soil, weather, climate, crop, etc which is used for further decision making. The role of big data in Agriculture provides an opportunity to increase economic gain of the farmers by undergoing digital revolution in this aspect we examine through precision agriculture schemas equipped in many countries [2]. Agricultural data generation method has been changing dramatically. With the wisdom agriculture proposed, widely used sensors promote the development of agricultural Internet of things greatly. Agricultural Internet of things generates a lot of agricultural data. We should use big data technologies to analysis the data. The emergence of cloud computing provide a reliable way to deal with these massive data.

2)Big Data and Characteristics in General:-

2.1)Big Data

Large number of data sources are present across the world that generate the data known as Big Data. Some of the largest sources of data are social media platforms and networks. Let's use Facebook as an example—it generates more than 500 terabytes of data every day. This data includes pictures, videos, messages, and more. Data also exists in different formats, like structured data, semi-structured data, and unstructured data. For example, in a regular Excel sheet, data is classified as structured data—with a definite format. In contrast, emails fall under semi-structured, and your pictures and videos fall under unstructured data. All this data combined makes up Big Data. So Big data is a massive amount of data sets that cannot be stored, processed, or analyzed using traditional tools. According to Winter Corporation's survey, the current amount of data is growing at three-time increases every two years [3]. Big data necessitates a collection of methods and technologies, as well as new kinds of integration, in order to extract insights from large, complicated information. Recently, big data has been applied to different points of healthcare, manufacturing, transportation, and financial sector

Often, big data is characterized by the three Vs. – data containing great Variety, coming in increasing Volumes, with high Velocity. The data can come from publicly accessible sources like websites, social media, the cloud, mobile apps, sensors, and other devices. Businesses access such data to see consumer details like purchase history, what they searched for or what they watched, their likes, interests, and so on. Big data analytics uses analytic techniques to examine data, thus obtaining and find out information like hidden patterns, correlations, market trends,, and consumer preferences. Therefore analytics help organizations make informed business decisions that lead to efficient operations, happy consumers,, and increased profits. The role of big data in agriculture provide an opportunity to increase economic gain of the farmers.

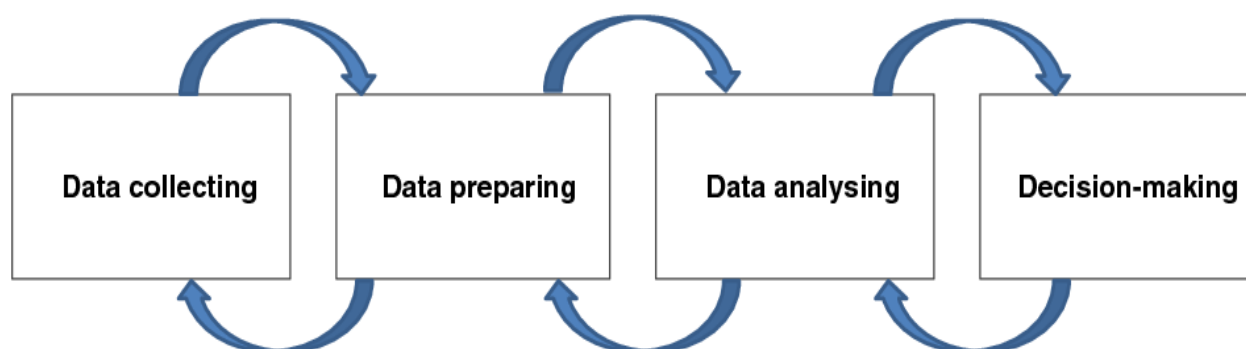


Fig -1 (Big Data Process of Decision Making)

Uses and Examples of Big Data Analytics

There are many different ways that Big Data analytics can be used in order to improve businesses and organizations. Here are some examples:

- Using analytics to understand customer behavior in order to optimize the customer experience
- Predicting future trends in order to make business decisions.
- Improving marketing campaigns by understanding what works and what doesn't
- Increasing operational efficiency by understanding where bottlenecks are and how to fix them
- Detecting fraud and other forms of misuse sooner

These are just a few examples — the possibilities are really endless when it comes to Big Data analytics. It all depends on how you want to use it in order to improve your business.

2.2) 5 V'S of BIG DATA

1. **Volume**: This refers to the size of the data being generated both inside and outside organizations and is increasing annually. Some regard big data as data over one petabyte in volume. It is getting vast as compared to traditional sources through which data used to be captured large amounts of data generated every seconds. (email, twitter)
2. **Velocity**: This depicts the unprecedented speed at which data are generated by Internet users, mobile users, social media, etc. Data are generated and processed in a fast way to extract useful, relevant information.
3. **Variety**: This refers to the data types since big data may originate from heterogeneous sources and is in different formats (e.g., videos, images, audio, text, logs). BD comprises of structured, semi-structured or unstructured data.
Data comes from various sources, machine generated and people generated and people generated different data formats.
4. **Veracity**: It refers to Trustworthiness of data and the quality of data,. By this, we mean the truthfulness of data, i.e. weather the data comes from a reputable, trustworthy, authentic, and accountable source. It suggests the inconsistency in the quality of different sources of big data. The data may not be 100% correct.
5. **Value** : This is the most important aspect of the big data. It is the desired outcome of big data processing. It refers to the process of discovering hidden values from large datasets. It denotes the value derived from the analysis of the existing data. If one cannot extract some business value from the data, there is no use managing and storing it [4][5].

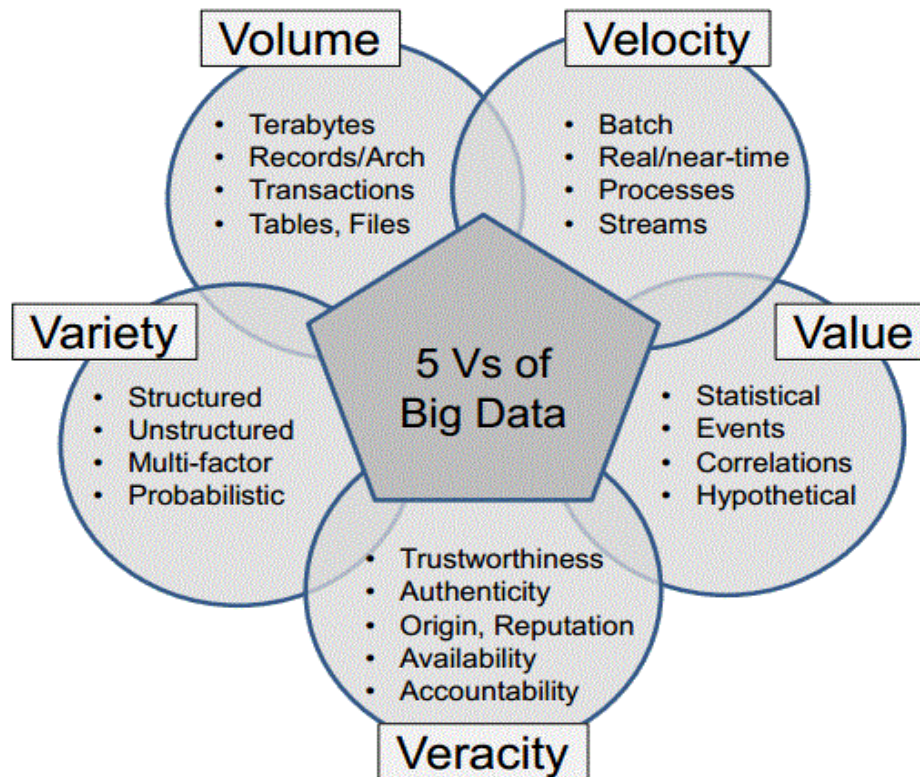


Fig-2 (Big Data Characteristics[6])

3)Big Data in Agriculture:

Big Data is playing an important role making good planning and policies for agricultural growth and development. Population growth and climate change are worldwide trends that are increasing the importance of using big data science to improve agriculture. In the agriculture community, big data is often viewed as a combination of technology and analytics that can collect and compile novel data, and process data in a more useful and timely way to assist decision-making [7].

Previously in the older day's collection of data was not digital. Over all big data made promises for the small-scale & large scale farmers a level of precision, information storage, processing an analyzing that was previously impossible due to backward technological usage. Technology has for advanced as by using application information can be logged, voice recognition made farmers more easy to handle the application. Agriculture management tools provide access to interacting with datasets[4].

At present times agricultural sector is leading towards the concept of smart agriculture. The concept of smart agriculture/farming refers to farm managing using data analytics, communications systems, IoT, ICT, sensors, GPS, satellite, robots, drones, etc. With all of these technologies, farmers can collect data, monitor the field conditions without physically going to the field, and make strategic decisions [5]. Big Data does not function in isolation. It has been used with other technologies such as ML, cloud-based platforms, image processing, modeling and simulation, statistical analysis, NDVI vegetation indices, and geographic information systems (GIS) [8].

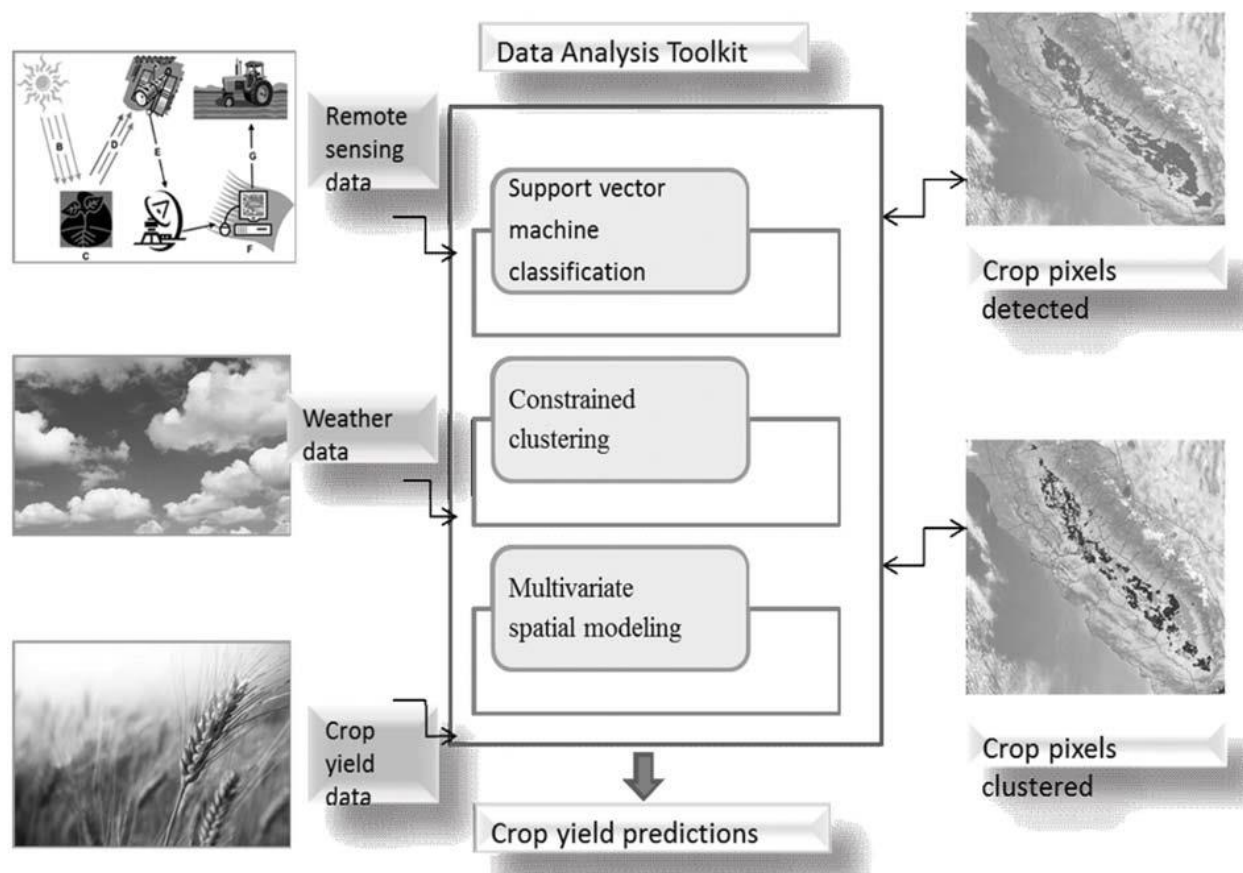


Fig-3 (Big data in agriculture [9])

3.1) The Role of Big Data in Agriculture

Big Data in agriculture involves the collection, analysis, and utilization of vast amounts of data to make data-driven decisions. This data comes from various sources, including sensors, satellites, drones, weather stations, and farm equipments. Here's how Big Data is making a significant impact in agriculture:

1) Precision Agriculture: It means doing farming with precision i.e. Right input at Right dose in Right place and in Right time [10]. Big Data technologies, such as GPS and sensor networks, enable farmers to collect large amounts of data about weather, crop health and soil conditions. This data is then analyzed to identify areas within their fields that require specific interventions as result optimize planting, irrigation, and fertilization, pestication etc so that there is higher yields and reduced resource waste.

2) Crop Monitoring and Disease Detection: Drones, remote sensors and Satellite provide high-resolution images of fields. Big Data analytics can process these images to monitor crop health, detect signs of disease, and identify areas that need immediate attention. This helps farmers take timely corrective actions.

3) Weather Forecasting: Advanced weather data analytics use historical and real-time weather data to provide accurate forecasts. Farmers can use this information to plan planting and harvesting schedules, reducing the risk of crop loss due to adverse weather conditions.

4) Livestock Management: Big Data can be used to monitor the health and behavior of livestock. Wearable sensors and data analytics help farmers track the well-being of individual animals, optimizing feeding schedules and detecting health issues early.

5)Supply Chain Optimization: Analyzing Big Data helps farmers gain insights into consumer preferences, market demands, and price forecasts. Data on crop yields, storage conditions, transportation routes, and demand forecasts are analyzed to ensure that agricultural products reach consumers efficiently and at the right time. This information can guide their production decisions, improve supply chain efficiency, and ensure better profitability

6)Market Insights: Big Data analytics provide farmers with valuable market insights. By analyzing market trends, pricing data, and consumer preferences, farmers can make informed decisions about which crops to grow and when to sell them for the best prices.

7)Soil Health Management: Soil data collected through sensors and laboratory analysis can be integrated with Big Data analytics to assess soil health. This information helps farmers determine optimal crop selection and planting techniques.

8)Water Management: Water management can be efficiently managed by IoT Technology to avoid the wastage of water using different types of sensors [11]. Big Data plays a crucial role in efficient water management. It helps farmers monitor water usage, predict droughts, and optimize irrigation systems to conserve water resources.

9)Financial Analysis: Big Data can assist in financial analysis for agricultural businesses. It helps farmers manage budgets, assess the return on investment for various crops, and make informed decisions about investments in equipment and technology.

10)Forecasting and risk management : Big Data analytics can help farmers anticipate risks such as extreme weather events, market fluctuations, or disease outbreaks. Such insights enable them to take preventive measures and reduce potential losses. Provide predictive insights to future outcomes of farming and drive real-time operational decisions[5].

11)Other Benefits:-There are some other advantages of big data in agriculture as –

- Increase productivity.
- Create a sustainable agriculture that is attractive to youths and future generations.
- Minimize agricultural expenditure.
- Stop migration of the labor force.
- Attract greater investments in agriculture industry.
- Ensure maximum consumer satisfaction.

3.2)Big Data Framework and Technologies for Smart agriculture

Big Data in agriculture involves the collection, analysis, and utilization of vast amounts of data to make data-driven decisions. This data comes from various sources, including sensors, satellites, drones, weather stations, and farm equipment. Big data provides farmers granular data on rainfall patterns, water cycles, fertilizer requirements, and more. This enables them to make smart decisions, such as what crops to plant for better profitability and when to harvest. The right decisions ultimately improve farm yields

Technologies used for big data agriculture analysis

IoT – Collect data from sensors , drones etc. IoT sensors on fields and crops can provide a significant amount of information, critical for the decision-making process such as soil conditions, high-fidelity weather conditions fertilising requirements, water availability and pest infestations [12]. In addition, tractors and other machinery are becoming more and more densely

1. equipped with sensors, some of them to improve operations while others collecting precious data for broader agronomic evaluation [13].
2. **Cloud Computing**- This allows the many different workloads involved in both operational and analytical processing. Cloud platforms(together with MapReduce) offer possibilities for large-scale storing, preprocessing, analysis and visualization of data .
3. **Machine Learning**-Analytical decisions by algorithms after data collection. To ensure that the information from big data is retrieved in the most efficient way possible there is a need to use effective machine learning algorithms to detect patterns within the data .
4. **Image processing**- image processing and machine vision are widely used in agricultural plants and vegetable analysis to solve the mentioned issues with manual approaches.
5. **GPS**- Global Positioning System satellites broadcast signals that allow GPS receivers to compute their location. This information is provided in real time, meaning that continuous position information is provided while in motion. Having precise location information at any time allows soil and crop measurements to be mapped .
6. **GIS**- Geographic information systems (GIS) are computer hardware and software that use feature attributes and location data to produce maps . while GIS are used in geospatial problems
7. **Big DataBases**- Big datasets are appropriate for the storing of large volumes of heterogeneous information,Hadoop is mainly designed to store and process the large set of data.

Table - Common software tools used for big data analysis in agriculture[14]

Sr. No.	Category	Software tools
1	Image processing tools	IM toolkit, VTK toolkit
2	Machine learning (ML) tools	Google TensorFlow, R, Weka, , scikit-learn, Mlpack, Apache Mahout, Mlib
3	Cloud-based platforms for large-scale information storing, analysis and computation	Cloudera, EMC Corporation, IBM InfoSphere BigInsights, IBM PureData system for analytics, Aster SQL MapReduce, Pivotal GemFire, Pivotal Greenplum,
4	GIS systems	ArcGIS, Autodesk, MapInfo,
5	Big databases	Hive, HadoopDB, MongoDB, ElasticSearch, Apache HAWQ, Google BigTable, Apache HBASE, MonetDB/SciQL, PostGIS, Oracle GeoRaster
6	Statistical tools	Norsys Netica, R, Weka
7	Time-series analysis	Stata, RATS, MatLab

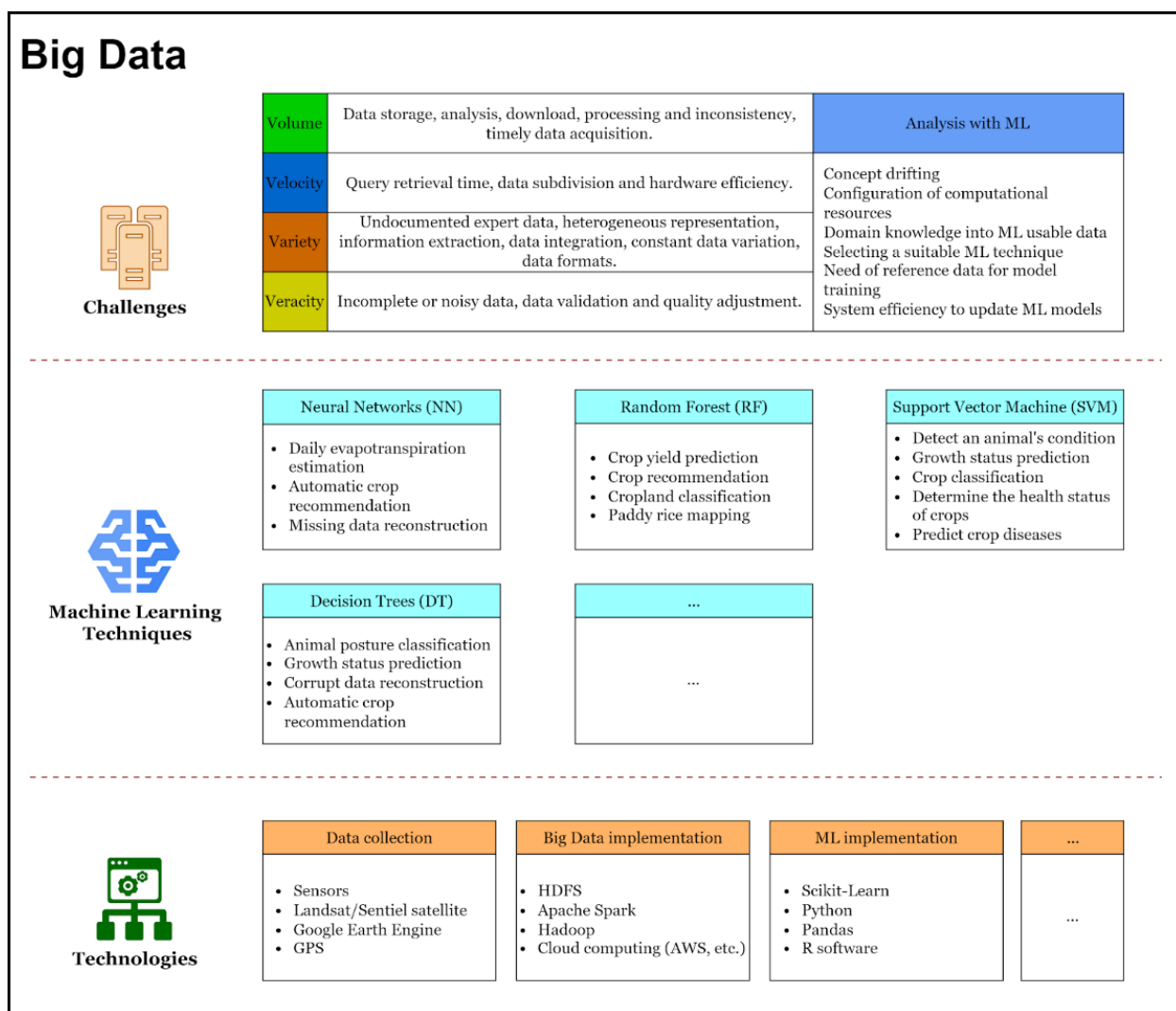


Fig-4 (Framework of big data in agriculture [8])

3.3)Challenges and Limitations of Big Data in Agriculture

Despite the promise and potential benefits that Big Data offers for the future of farming, there are several challenges and limitations that need to be addressed in order to fully realize its value. By overcoming these barriers, farmers can benefit from data-driven insights and make informed decisions to optimize their operations and improve productivity

1)Data collection :-One of the main concerns is data collection and privacy. there is a lack of standards and common solutions for data collection, preparation and storage. In addition, there is a lack of data for many reasons, farmers did not record their data and it takes time to build significant historical Datasets [15]. To move data from equipment to servers, farms usually have to have access to the Internet, which is still challenging even in many rural parts

2)Data Privacy .: Farmers may be hesitant to share sensitive information about their operations, fearing that it could be misused or compromised. Data have to be collected in a consistent fashion and compliant with protocols that allow it to be pooled into centralized servers that must be protected from cyber security attacks while hiding the identity of individual farm managers [16]. Farmers should have control over their data and decide who can access it.

3) Technical infrastructure requirements:- Another challenge lies in the technical infrastructure requirements. While Big Data solutions offer valuable insights, they rely on advanced technology and reliable internet connectivity. Many small-scale farmers may not have the necessary resources to invest in such infrastructure. Efforts should be made to provide affordable access to these technologies and ensure reliable internet connectivity in rural areas.

4) Access and affordability :- Access and affordability are significant issues for small-scale farmers. Implementing Big Data technologies can be costly, limiting access for farmers with limited financial resources. Moreover, training and education on how to effectively use data-driven tools may be lacking in the farming community. To address these concerns, initiatives should be taken to make Big Data solutions accessible and affordable to all farmers, regardless of scale.

5) Analyzing and interpreting large datasets effectively- The availability of large datasets from diverse sources is necessary to achieve better generalization[17]. Analyzing and interpreting large datasets effectively is another challenge. Inadequate staffing or skills for big data analytics were also found to be hurdles to implementing and improving big data analytics in reports by The Data Warehouse Institute (TDWI) [18]. Offering specialized training and support to farmers can help them utilize Big Data effectively and maximize its potential benefits

4). Conclusion and Future Work

Big Data is a game-changer in the agricultural sector, offering farmers the tools and insights needed to enhance productivity, reduce waste, and ensure food security. It has become the boom to agriculture sector and it is to be one of the best systems for crop planning to increase agriculture productiveness. Ensuring the modern farming operations with Big data technologies to be successful is a very significant research domain. As technology continues to evolve, we can expect even more innovative applications of Big Data in agriculture, helping to address the challenges of feeding a growing global population while minimizing the environmental impact of farming practices. In this study, the big data technologies, roles and challenges of big data in agriculture are discussed briefly and the future need of research are also suggested as per the growing demands.

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