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Promoting digital agriculture through big data for sustainable farm management

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ABSTRACT: Digitalization of agriculture may be a solution to feed a huge growing population in the future. Application of big data is a key tool to digitalize the agriculture sector. Though there is a long debate on its applicability to agriculture, this study aims to address how big data technology contribute to digital agriculture in terms of sustainable farm management. The study uses an extensive review of current research work and studies in agriculture for exploring the best and compatible practices which can help farmers at field level for increasing production and improving quality. This study reveals several available big data technologies and practices in agriculture for solving the current problems and future challenges at the field level. The study reveals that application of big data technologies in agriculture is growing but still at low level. It also explores that there are a few technologies used for crop production, plant protection, livestock production, fisheries, post-harvest management and market development. The study finds out some challenges such as privacy of data, data availability, quality and openness, financial investment, lack of expertise and context specific technology. The study recommends that a large-scale adoption of agricultural big data technologies require government initiatives, a public-private partnership, the openness of data, financial investment and regional basis research work.

KEYWORDS: Digital agriculture, smart farming, precision agriculture, big data, agricultural sustainability.

1 INTRODUCTION

Digital agriculture is a kind of agriculture which uses modern technology achieving sustainable agricultural development in terms of crop, fisheries and livestock. Modern agricultural practices adopt digital technology for the transformation of traditional agriculture to modern agriculture. It covers virtual agriculture, information and lean agriculture and so on. The transformation from traditional agriculture to digital agriculture requires a huge amount of data from almost all stages of crop production, fisheries and livestock production. Digital agriculture is now a holistic approach which uses the knowledge of information science, environmental science, computer and software engineering, system science, GIS (Geographical Information System), GPS (Global Positing System), remote sensing technology, and virtual satellite imaging for better integration with soil, climate, environment with agriculture [1]. Shi-Wei [2] mentioned that digital agriculture is a key to agricultural informationization and better means of agricultural production even in the countryside. Now the world population is more than 7 billion which will be around 9.6 billion by 2050 [3]. The income level of the people to buy enough food i.e. the

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middle-income people will be 5 billion by 2030. But rest 4.5 billion people may suffer from food insecurity. For feeding these people, the agricultural production should be doubled within a short period of time. It is a major challenge for humanity. The only way to increase the targeted food production by using modern sophisticated technology in every step of agricultural production i.e. using big data in agriculture [4]. The digital agriculture will increase farmer's growing needs of food in the future. Big data technologies are the tools to collect a huge amount of agricultural data at the minimum cost which stimulates the insight-driven, productive and efficient agricultural production.

Big data analytics is an important tool for big data driven agriculture. It can extract data a huge amount of data and take the quick suggestion. The trend and correlation among data are easily done by big data analytics. According to Zhang et al. [5], productivity can easily increase by the application of digital agriculture with big data technologies. The improvement of productivity is about 10 to 15% in the crop agriculture [6]. Though the application of big data in agriculture depends on multiple factors like user acceptance of new technology, the willingness of stakeholders, data ownership, privacy and control but it works at the field level [1]. The decision of farmers on the adoption of new technology is influenced by various social and economic factors. For digital agriculture, it is more complex because of new sophisticated technology like smart devices, network infrastructure, technical expertise and knowledge of analytics.

Digital agriculture can generate specific information of the status of soil, crop, fish, animal and intercultural management requirements which can easily help to manage farm properly. Some scholars showed that their positive consent on big data application for ensuring digital agriculture [4], [7], [8] but some others showed opponent and negative attitude towards the suitability of the application of big data technology in agriculture [9], [10], [11]. This study focuses the specific digital technologies which will help farmers as well as related stakeholders to manage agricultural farm in a sustainable way. Therefore, this study is an attempt to explore the suitability of the application of big data for sustainable farm management through digital agriculture approach. The study will help to develop policy and program regarding the capacity building of farmers for sustainable agriculture development through big data driven digital agriculture.

2 METHODOLOGY

This study is based on extensive desk literature review. The study surveys the available literature from 20120 to 2018. The period is selected because of the initiation of big data technologies as the big data technologies are a new phenomenon. The study is followed two inclusions criteria like availability of full article and big data technology related to farm management and also two exclusion criteria such as available literature published in English language and article focusing technological design. Similar methodology has been used by some other researchers [12], [13], [14], [9]. Data has been collected by using some keywords like "big data, agriculture, digital, precision agriculture, smart, farming" in the renowned data bases such as a web of science, engineering village, Springer link, science direct and Google Scholar website. Finally, 29 documents have been identified for qualitative analysis. This qualitative document selection has been done by following the checklist of the Reporting of Observational Studies in Epidemiology (STROBE) [15]. Since literature review is a rigorous, and systematic process so it can be considered as original work [16]. Digital agriculture and big data related documents consisting of journal articles, working papers, book chapter, magazine article, and books have been reviewed to explore the suitability of the application of big data in agriculture.

3 CONCEPTUAL FRAMEWORK

Leveraging big data technologies to agriculture is a potential way to achieve the goal of digital agriculture. According to Ma et al. [17], big data analytics help to create novel value for leveraging these technologies to any sectors through three major components such as new sources of digital data, more computing power and expertise in analytics. Only 5% data in the globe is structured data which is generated from sensors, social media and search engines. According to Bronson and Knezevic [18], all kinds of farmers need to adopt big data technologies for meeting the needs of food and agriculture. Big data provides an opportunity to make a long-term relationship among various stakeholders of food and agriculture. Though big data drove agriculture did not get proper attention from the concerned authority like policy makers, administrators, academician and practioners but no one can deny the importance of big data in present days. Now it is the high time to adopt the big data technologies for sustainable agriculture. It provides a new sight of scholarship for maintaining the connection between big data and practical use of data in the farmer's farm. According to Kamilaris et al. [14], various agricultural issues can be easily solved by using big data analytics by administering various algorithms, approaches and strategies. Schonfeld et al. [19] argue that modern technology like GPS is very much helpful for crop and livestock farming. Big data technology can help various stakeholders like farmers, agricultural machinery manufacturers, input suppliers, businessman and related policy makers for avoiding the unexpected situation and getting proper benefits.

4 BIG DATA IN AGRICULTURE

The study identifies big data based agricultural technologies which are directly applicable to the farm level management. The study gathers the related technologies for sustainable farm management. Though the use of big data concept is relatively new but it has huge potential for sustainable farm management. According to Coble et al. (2018), big data is a large, multidimensional, complex, and distributed data set which generated from a various medium like internet sources, satellites, daily official queries, peoples purchasing behaviors, opinions and social media. Big data in agriculture is actually applied for a combination of all available modern technology and data analytics for taking a decision which is only dependent on data. The typologies in digital agriculture are as shown in Table 1.

Table 1. Typologies in digital agriculture

Typology	Features	Researchers
Agricultural big data	A lot of data collected from various sectors and stages of agriculture. Stored and processed in the computer for use and reuse for decision making.	Zhang et al. [5]
Precision agriculture	Sensor enabled hardware and software tools to manage agriculture in all aspects using modern technology.	Coble et al. [20], Pham et al. [21], Reddy [22]
Prescription agriculture	Computer algorithm enabled prescription for agronomic practices for mixing yield.	Himesh et al. [23]
Enterprise agriculture	Computer enabled agribusiness platform considering field agriculture to human resources management, inventory, logistics, machinery, buying and selling the system, and profit.	Schleusner [24], Grady and Hare [25], Van [26]
Automated agriculture	Automation in agriculture through robotic technology and intelligent program using farm data and environmental data.	Wu et al. [27], Bronson and Knezevic [18]

Source: Author's compilation

Coble et al. [20] also refer big data based on its characteristics such as volume, velocity, veracity, and variety with volume as the size of data, velocity as the flow of data, variety as structure or design of data and veracity as the credibility and the accuracy of the data. The digital transformation and evolution of technology in agriculture sector are shown in Table 2.

Table 2. Digital transformation and evolution of technology

Timeline	Technology
1960	Computer innovation
1992	Web creation
1994	Online sales
1995	Social networking innovation
1999	Mobile app development
2008	Initiation of digital phase

Source: Author's compilation

Agricultural big data can be used by a holistic approach comprising variously related technology and related sector's data. No single source's data are not enough to make a proper decision. Data should be collected from different sources like soil related data, intercultural management related data, climate-related data, long-term census data, harvesting data, cropping pattern data, and agribusiness data [19]. Digital agriculture combines the concept of core agricultural disciplines with computer science, machine learning, software engineering, environmental science, human resource management, risk management and disaster management [28]. It deals with crop management related inputs such as seed, fertilizer, agro-chemical, soil management, field characteristics and weather (Figure 1).

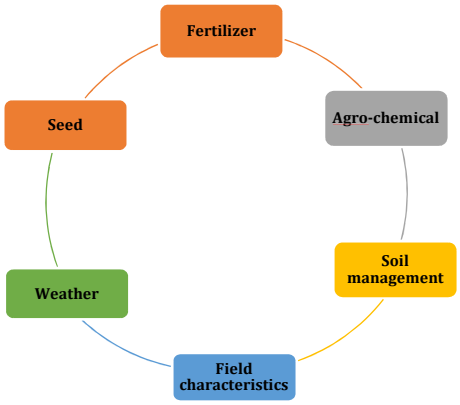

Fig. 1. Digital agriculture input model

Source: Adapted from Kearney [7]

5 DIGITALIZATION OF AGRICULTURE

The study reveals some potential technologies which is based on big data technologies and can help farmers at field levels. The big data based digital agricultural technology can help farmers from the field preparation to harvesting such as weather forecasting, crop yield prediction, crop selection, irrigation management, crop diseases and pest management, agricultural marketing and agricultural pest management.

5.1 WEATHER FORECASTING

Edaphic and environmental factor has a great influence on crop cultivation, fish cultivation and livestock management. Since various stages of crop plant require different temperature and humidity, so it is necessary for the farmer to learn about useful temperature and humidity that can be easily known by using big data analytics. Big data technology provides an opportunity for farmers to take decision for better crop management by analyzing different stages of crop cultivation such as planting time, intercultural operation, fertilization, pesticide management and harvesting [29]. Farmers can easily avoid any adverse situation from weather forecasting. Similarly, a farmer can take a decision about the soil management since the soil is also related to environmental factors. A farmer can get weather forecasting by using Support Vector Machine which is based on machine learning technique [30].

5.2 CROP YIELD PREDICTION

Farmers can get the probable harvesting time and yield of the crops by using big data technologies through analyzing a various effective algorithm. By using this useful information, farmers can easily avoid yield harvest lost and manage the post-harvest activities [30]. Big data technologies help the farmer to get more yield by finding proper harvesting time which also helps to avoid any adverse climatic conditions.

5.3 CROP SELECTION

Big data technology helps the farmer to select proper crop through using algorithm analysis of input and output variables of a crop. There are some popular techniques which are used frequently for crop selection such as K-mearest neighbor, decision tree and artificial neural network. Big data technology usually analyzes natural calamities, climate, famine, soil and other inputs for finding out an appropriate crop for a specific area [31].

5.4 IRRIGATION MANAGEMENT

Irrigation is an essential intercultural management factor for crop production. An accurate time and proper water supply can improve plant health otherwise it will be fallen into various problems like stunt growth, pest attack and wilting. Most of the developing countries face variability of climatic change, rainfall and drought. The smart irrigation system may be a solution

for farmers to take a proper decision on irrigation. Big data technology can easily predict the irrigation requirement of the crop by using an artificial neural network [32].

5.5 CROP DISEASES AND PEST MANAGEMENT

Disease and pest infestation of the crop is a normal phenomenon in crop production but it reduces the quality and yield of the crop [31]. If a farmer can control the disease and pest infestation, it will help to increase yield. Big data provides this opportunity to detect any disease infestation on the crop for which farmers can easily take measure to control the disease and the safe the crop. Thongboonnak & Sarapirome [33] reported that big data technology can predict the pest attack in advance. Rumpf et al. [34] explore that support vector machine is useful for crop disease infestation.

5.6 AGRICULTURAL MARKETING

Market information is necessary for getting profit from agricultural products. A farmer may incur a loss on their product due to ignorance about the market information. There are various kinds of market data such as input cost, price trends, demand and supply, cultivation cost, wages, marketing and transportation cost. Farmers can take decision easily from the result of big data analytics of these market information [35]. The government can use the big data technology for market analysis and take proper monitoring on market.

5.7 AGRICULTURAL POLICY FORMULATION

Agricultural policy has a vital influence on agricultural production at farmers' level as well as national level. It is more critical especially in the agriculture oriented developing countries. Since there is a huge amount of agricultural information so it is really very difficult to handle without proper technology. Besides, an appropriate agricultural policy requires a proper data analysis. Big data is a key tool for analyzing these huge data and make a proper policy decision. The government can use big data analytics for the formulation of agricultural policy by analyzing huge data related to agriculture [36].

6 CONCLUSION

Sustainable agricultural development is now a prior issue to feed the growing population in the future all over the world. The study focuses on the suitability of the big data technologies in the agriculture sector. Big data is a potential tool to contribute to the transformation of traditional agriculture to modern digital agriculture from farm to fork at the time of technological development. It addresses all the complexities related to farming systems analyzing farmer's need, consumers need, financial efficiency, marketing efficiency and other stakeholder perspectives. The study reveals that the application of big data technologies in agriculture is growing but still at low level. It also explores that there are a number of technologies used for crop production, plant protection, livestock production, fisheries, post-harvest management and market development. The study finds out some challenges such as privacy of data, data availability, quality and openness, financial investment, lack of expertise and context specific technology. The study recommends that a large-scale adoption of agricultural big data technologies require government initiatives, a public-private partnership, the openness of data, financial investment and regional basis research work. Though this study highlights the non-technical side of the application of big data technologies, it will help the policy makers, IT experts, practioners, political leaders, researchers to design and formulate policy for promoting digital agriculture.

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