sdmimd
JOURNAL OF MANAGEMENT

DOI:10.18311/sdmimd/2023/33006

A Perspective on the Application of Artificial Intelligence in Sustainable Agriculture with Special Reference to Precision Agriculture#

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Abstract

Agriculture has undergone rapid technological changes in the search for greater productivity. At the same time, environmental changes, agricultural crises from the possible repercussions of climate change and the different uses of land and technology make tools that look to minimise the negative aspects of the environment and human beings increasingly necessary. In this context, the concern with sustainability is imperative. Different agricultural systems have been trying to connect with this issue, making the term sustainable a field of conceptual, political, ideological, and power dispute. On this note, Artificial Intelligence (AI) can be used to enhance sustainable agriculture's growth prospects. Therefore, this paper analyses how AI could aid sustainable agriculture, keeping in mind the accessibility challenges for small and marginal farmers. The paper will also explore the prospects of agrometeorology and precision agriculture as a concept and how it would play a significant role in smart harvesting. Finally, the documents will also look to oversee the influence of AI in agroecology. The article will also explore the common grounds between Indian and Brazilian agriculture, especially the small and medium farmers scenario, their challenges in accessing this technology, and how the government could aid the use of these technologies through inclusive policy interventions.

Keywords: Agroecology, Agrometeorology, Artificial Intelligence, Efficiency, Sustainability

1. Introduction

Agriculture has undergone rapid technological changes in the search for greater productivity and sustainability. The sector requires the support of technological advancement to ensure clean, green, and effective agricultural practices. In this context, the concern with sustainability is imperative. Different agricultural systems have been trying to connect with this issue, making the term sustainable a field of conceptual, political, ideological, and power dispute. Here, sustainable agriculture will be understood as a process or even an ideal type of reference. In other words, agricultural processes consistent with the view of land use, concerned with the ability to support the economic, social, and ecological functions of agroecosystems, are suitable for this category, understanding the maintenance of biodiversity as a critical element. Given the diversity of ways of life, agricultural practices, environment, history, potentials, and weaknesses, it is assumed that there may be variations in these processes. In other words, agricultural processes

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#This is the modified version of the paper presented in the 7th International Economics Conference on "Economic Growth and Sustainable Development: Emerging Trends" organised by SDMIMD, Mysuru on November 24-25, 2022.

consistent with the view of land use, concerned with the ability to support the economic, social, and ecological functions of agroecosystems, are suitable for this category, understanding the maintenance of biodiversity as a critical element. Given the diversity of ways of life, agricultural practices, environment, history, potentials, and weaknesses, it is assumed that there may be variations in these processes.

Artificial Intelligence (AI) is currently in the context of technological transformations in agriculture. "*In the simplest terms, AI, which stands for artificial intelligence, refers to systems or machines that mimic human intelligence to perform tasks and can iteratively improve themselves based on the information they collect*"[1]. We also can say that "*AI is much more about the process and the capability for superpowered thinking and data analysis than any format or function*"[2]. Although AI mentions images of high-functioning, human-like robots taking over the world, AI is not intended to replace humans. It is meant to enhance human capabilities and contributions significantly. That makes it a valuable business asset.
There are diverse ways to think about and practice agriculture. One example of this is the difference between the agriculture of agroecological bases and conventional agriculture. So, technologies and AI cannot apply to all places in the same way. It demands a look at their adaptations to local conditions. Thinking about the concept of sustainable agriculture delineated, AI can be used for: pest detection; soil and crop health monitoring; smart irrigation management; increase in production; and Agrometeorology smart harvesting.

With the advent of information technology, innovation associated with computer data has been highlighted as an essential ally for increasing agricultural productivity while keeping sight of the parameters necessary for a trajectory of sustainability. Precision agriculture is a production management system that supplies the background to connect production platforms to information technologies and Artificial Intelligence. The association of these elements makes it possible to generate a large amount of data for monitoring production conditions (soil, culture, climate, water...). Agrometeorology is also included here, with its decision-making support systems based on models, which introduce the climate factor in data management.

All these aspects are highlighted as positive, but for the producer to be engaged, there must be sources, training, and service providers that support them. A technical dimension is associated with the process, and a socioeconomic and cultural dimension (including how farmers mobilise, think, and practice agriculture in distinct locations on the planet). A challenge in this technological field is how to integrate the social aspects present in rural, for example, India and Brazil, with a diversity of producers, economic conditions, biomes, cultures, and climate.

So, it is vital to think about not only the perspective of the farmers but also the real condition of the use of this system. There are crucial factors like costs, physical infrastructure, distance, and knowledge, among other things, which can generate new elements of exclusion in the field and reproduction of power by digital tools. In addition, although it is not the focus of the present work, it is worth mentioning that there still needs to be a gap in the rights to use data collected on farms by digital equipment suppliers. How will this information be used and stored? How will this data be protected? With the end of the contract with the technology company, what happens to the data collected? Many issues still permeate this production system and whose legislation has been studied.

With the above considerations in mind, the study aims to analyse the need for and importance of precision agriculture and agrometeorology in contemporary-day farming. To Introduce a model for accessing AI services and suggest policy recommendations to the government.

1.1 Research Methodology

The study is based on a descriptive analysis where data are accessed from secondary resources, renowned journals, research papers, government reports, and newspaper articles. Various charts and other analysis-friendly flow diagrams are used for better representation of data. Although the next topic refers to the Literature Review, the fundamental basic concepts will also be worked on throughout the following items based on the literature in the area.

The last part of the text refers to constructing a model of AAUIs (Agromet Artificial Intelligence Units). For that, outline the use of a heuristic method. In specific fields of study, heuristics can be defined as a mental shortcut or a series of simplification strategies to seek the resolution of complex problems, reducing their level of difficulty (Cortés, 2015). Although a mental tool is being used here, this method uses prior knowledge of the object to be worked on. It starts with the general knowledge of the problem and then simplifies it, seeking a resolution according to the claimed aim. From this assumption, the mental construction of an AAUI model is inserted, presenting it as a simple heuristic to solve the problem of access of small agricultural producers to the tools of digital agriculture.

2. Literature Review

In general, and using the perspective presented by Talaviya *et al*., (2020; 59) AI technology is made by studying how the human brain thinks and how humans can learn, decide, work, and solve problems. Based on this perspective, software and intelligent systems are created. Software is fed training data, while smart devices offer the output for each valid input, like the human brain. In set, while AI is the science of making intelligent machines and programs, Machine Learning (ML) is the ability to learn something without being programmed, and Deep Learning (DL) is deep neural network learning. Both form the essential parts of AI.

Galaz *et al*., (2021) cite the term "Artificial Intelligence" (AI) when referring to technologies that employ Machine Learning (ML). When AI appears as part of a technology that employs computational data, such as an intelligent tractor, the term AI and "associated technologies" are used. According to the authors, technologies that use AI as a basis are gaining ground in various fields of research and use, primarily related to the themes of sustainability and climate change. Among the sectors that have emerged in the use and development of these tools is the agricultural sector, through precision agriculture, a concept that will be discussed in another topic.

This impulse in the agricultural sector is linked to the concern with using scarce resources, such as the rational use of water and soil, among other factors. According to the authors above, the interactions between humans, machines and ecology, which are present in this sector, create conditions for adaptive systems. These, in turn, contribute to "Distributed AI" (DAI), decentralised systems that gather information across domains, capable of reacting autonomously, adapting, and acting proactively to changes. This system can help understand the continuous changes in agricultural systems due to human activities and climate change.

It is important to note that Bronson (2022) brings a critical perspective on using AI, and the big data to them associated with agriculture and its social context. Bronson (2019, p. 583) defines Big Data as voluminous data collected from unconventional sources into computer-stored datasets that computer algorithms can mine; "*data drive on-farm or systems-level decisions from past behaviour or environmental or business modelling (e.g., when best to seed)*". The author explains that in the same way that chemical and machinery technologies are concentrated in the hands of a few corporations, agricultural data, even if generated by farmers, follow the same path. It occurs with the farmers' acceptance that knowledge is needed to manipulate these data. Nevertheless, on the side of the large conglomerates, access to farm-level data enables them to develop profiles of farmers by location, for example, targeting advertisements for different products in the sector. A fact that can contribute to expanding the historical relations of power and economic dominance in the world food system.

Contrary to this critical view, there is the aspect that the use of open data, especially for developing countries, can help to overcome many challenges that the agricultural sector is facing today. However, this view runs against the technical difficulties of operationalising information sharing for environmental and social well-being. Recognising this contradiction, the main concern in this paper is not to work on the technical aspect related to data sharing but to try to raise some positive elements in the use of AI, able to lead to inclusive social changes within the food system. According to Bronson (2022), it is necessary to understand that the theme of agricultural sustainability now incorporates not only the best conservation practices, among other aspects at the farm level but also the focus on technology, where AI serves as the basis. The concern that arises is that the same discourse previously brought by the Green Revolution in the 20th century is now being rescued through the bias of Big Data. That is, digital agriculture is necessary to feed the world's population and preserve the environment, but it is reduced to helping a small part of society, creating new exclusion scenarios.

A pertinent question is: What has been the biggest driver of the digitization of agriculture and AI so far? The problem is that the profit and the availability of technologies stand out as the focus, even in the face of a growing discourse on the needs of agriculture, the environment and society. As highlighted by Schimpf (2020), that is why it is increasingly important to make this topic more present in the public debate and agricultural intervention processes. Leaving this tool, and the information it provides, as domain and usufruct mainly to large corporations in the sector, will widen the gap between these and small properties and productions, especially in developing countries. Given the challenges that today's world has brought, the digital divide can negatively impact some segments' agricultural production capacity. Thus, while the use of digital agriculture and artificial intelligence can contribute to solving the challenges of the agri-food sector, more excellent planning, debate on rules and the creation of clear long-term policy objectives in this domain are urgent. Looking to neutralize asymmetries, some institutions have worked against the monopolization of this tool, supporting the imposition of specific rules and open data[3] policies. For instance, GODAN (Global Open Data for Agriculture & Nutrition) forms a global network that debates and defends open data initiatives. It is argued that growing populations and unpredictable environmental changes impact global food systems (GODAN, n.d.).

Following, we continue with the literature review based on chosen topics.

2.1 Importance of Precision Agriculture and Agrometeorology in Contemporary-Day Farming

The accelerating growth and innovation in science and technology and its extended relevance in agriculture give us the scope to promote the practice of sustainable agriculture. These technologies are no longer a want but a necessity for farmers as they face many Agri-oriented issues in recent times. It can also be assumed that the challenges that these farmers are going face are going to be bigger than what we could imagine. Some of the problems they could face can be mitigated and eradicated if they could predict the possibility of their occurrence. One of the most causal issues is plant pathogens and their associated diseases.

He and Krainer (2020, p. 933), mentioning Savary *et al*. (2019), comment that plant pathogens and pests are responsible for up to 40% of corn-starch, potato, rice, soybean, and wheat crop yield losses worldwide. Furthermore, plant diseases caused by bacteria, fungi, nematodes, and viruses impose high costs on the global economy, around USD 220 billion annually. He and Krainer (2020) also detail, citing the study of Nicaise (2014), that viruses make up almost half of the plant disease-causing pathogens. These handle an annual global cost of around USD 30 billion. For example, "*rice is cultivated in one hundred countries, supporting nearly half the world's population. It is at risk from multiple vector-transmitted viruses at the cost of USD 1.5 billion annually. In 2019, the International Committee on Taxonomy of Viruses recognised 1484 plant viruses. Like animal viruses, plant viruses are grouped based on viral genomic structure*" (He & Krainer, 2020, p. 933).

Therefore, it is important to detect, trace, and treat these issues before they become a global food security concern.

Faced with the challenges, agriculture is one of the many sectors that can receive help from digital transformation, using information and communication technologies aimed at their problems. The technologies/tools related to this scenario are Big Data and Data Science, Artificial Intelligence (AI), Virtual Reality, Robotics, and Machine Learning.

According to Kar, Kumari and Singh (2022), AI is a tool that allows machines to solve problems, learn and integrate various human functions, such as perception, memory, language, or planning. Using data sets, facts, and knowledge to make predictions, AI can help preserve the environment by identifying factors such as emissions and energy reductions, CO_2 reduction, deforestation, climate change, plant disease, and accident prediction, among other aspects of sustainability in agriculture. Mentioning the work of Hill (2018), one of the examples brought by the authors as an area of application of AI is in the management, treatment, transport, and recycling of water. AI and "machine learning" tools can effectively treat and detect harmful particles in water. Moreover, algorithms and approaches used for wastewater treatment can continually adapt to new information. It is noteworthy that one of the problems is the need for specialists to interpret data. In addition, algorithms have been created to monitor soil quality and crop health, make predictions, and analyse climate variability for crop growth, working with other tools such as drone images.

3. Transformations in Agriculture and the Recent Demands

Since the beginning of the 20th century, agriculture has been going through increasingly rapid stages of technological transformation. At the beginning of the century, the main character was the use of hand tools and animal traction. Over time, advances were made in mechanisation and developing fertilisation, planting, and harvesting techniques. After the middle of the century, more specifically in the post-war period, the use of chemical products in crops was associated with innovative technologies. It is only recently that precision agriculture was inaugurated, with the evolution of machines, computational support, and improvement of implements to increase the efficiency of agricultural activity.

It should be noted that this increase in efficiency does not necessarily mean sustainability. It is worth noting the advance of monoculture and the loss of biodiversity in many of the globe. In any case, precision agriculture, through machines and sensors, uses satellite images, for example, which has allowed the consolidation of a database with relevant information from the field.

The demand for sustainability, however, has launched challenges in this area when they point to the need for technological aspects that combine production systems friendly to the environment. There are advances in the areas of ecologically based agriculture. Systems are becoming more complex, and the environment is launching new challenges. These new challenges introduce digital technologies to the context of precision agriculture, with the development of tools that consider the social, biological, environmental, and economic aspects of using technologies. Therefore, it is associated with the context of precision agriculture, digital agriculture, using data mining technologies, high-performance computing, modelling and simulation, computational algorithms, supercomputers, analysis and modelling tools, and information networks of different complexity (Massruhá *et al.*, 2020).

In short, according to the definition published in January 2021, by the International Society of Precision Agriculture (ISPA)[4]: "*Precision Agriculture is a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability, and sustainability of agricultural production*".

Table 1. Technologies used in precision agriculture

Technology	Uses	Benefits to farmers
Drones	**Agricultural mapping and field scouting.**	**Effective Application of fertiliser and pesticides.**
Mobile applications	Soil sampling and analysis	Instant information about soil health.
GPS /Satellite	Access to Geospatial data and effective management of resources.	Helps in planning the irrigation and use of other organic chemicals
Farm automation and robots	Faster reaping of the crops	Eases the work of farmers
Internet of things	Sensor and voice recognition access	Faster and hazel-free implementation.

Source: Elaborated by the authors

Precision Agriculture relies upon specialised equipment, software, and IT services. It includes accessing real-time data about the conditions of the crops, soil, and ambient air, along with other relevant information such as hyperlocal weather predictions, labour costs, and equipment availability. The real-time data is collected via sensors in fields that measure the moisture content and temperature of the soil and surrounding air. Satellites and robotic drones can also supply farmers with real-time images of individual plants. The technology in this process helps efficiently use land, water, fuel, fertiliser, and organics inputs; searching will ensure sustainability by reducing cost and environmental impact. Examples of these technologies are shown in Table 1.

It is important to note that artificial intelligence tools are used in the field and other links in the agricultural production chain, with potential benefits for all, according to Figure 1. Considering this more extensive scope of the agricultural production chain, examples of digital technologies that can be used in the agricultural production chain: are applications and software; cloud computing; machine learning, remote, and proximal sensors; automation and robotics, 3D printing; digital platforms; information systems; big data;

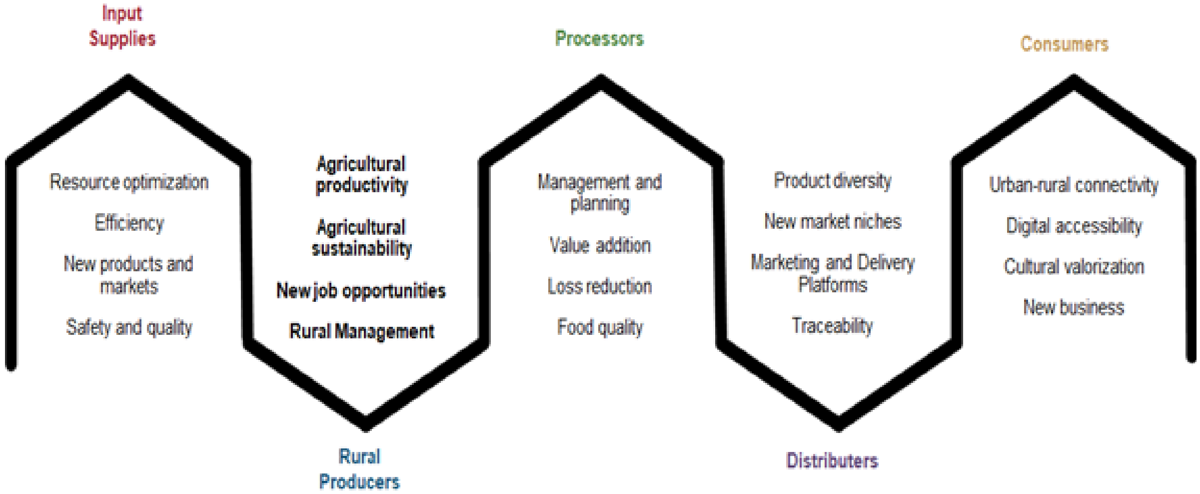

Figure 2. Potential benefits of digital transformation in the agricultural production chain.
Source: Based on Bolfe *et al.,*(2020).

artificial intelligence; social networks; GPS Systems, Blockchain and Encryption, Internet of Things,

Scenario for Agriculture Transformation in Northeast Brazil

The Brazilian Northeast region is characterised by a lower-income rural population and the Family Farmer (FF) predominance, mainly focused on the local food diet. 59% of the extremely poor in Brazil are concentrated in this region (Brasil, 2011). The FF consists of small farms, with the predominant use of family labour and family income originating predominantly from the rural area. The Northeast (NE) concentrates almost 60% of the FF of the country (Teixeira, 2019).

Furthermore, the NE covers 18.27% of the Brazilian territory, with 1,561,177.8 km², of which 1,007,438 km² cover the semiarid region, that is, 64.53%. This region is characterised by irregular rainfall distribution, low annual precipitation (less than 800 mm) and elevated temperatures. The Caatinga is the seasonally dry forest exclusive of the Brazilian Semiarid. More than one million and 260 thousand km² in 1,440 municipalities in eight states in the Northeast and northern Minas Gerais state (in the southeast) are susceptible to desertification. In 10 years, deforestation in the Caatinga has reached an area equivalent to Portugal (almost 50% of its extension is vulnerable to desertification) (Fortini, 2020)[5].

In these regions, vegetation no longer responds to rain, so the problem goes beyond the prolonged drought. Agroecology and its ecological principles associated with agricultural practice then become a necessity. Conventional agriculture, with deforestation practices, burning and using poison and chemical fertilisers, increase the environmental damage making the production more expensive and challenging to support small production. The population depends on agriculture to survive and complement its yield.

The impacts of climate change tend to alter crop standards. Thus, evaluating the relationship between vegetation, crops, water, soil, and environmental drivers is necessary. From this information, it is possible to find the dominant forces in the environment that trigger challenges that must be overcome. In this way, AI can be an essential tool.

In partnership with other institutions, the Embrapa (Brazilian Agricultural Research Corporation)[6], a public corporation, developed two technologies in 2018. The AGLIBS 1.0, an AI tool for soil mapping, soil carbon analysis (C), texture (sand, silt, and clay contents), and pH; and the SpecSolo®, for soil analysis by near-infrared spectroscopy that uses Big Data and Artificial Intelligence techniques, developed with a database with more than one million soil samples of Brazil. The question is, does this type of technology reach small producers?

4. Agrometeorology

The growing unstable weather pattern in the world makes harvesting difficult for farmers, especially those with limited land access and other natural resources like water. The 21st-century technological development surprised us with its growing trend in scientific inventions, and in the years to come, these trends will surprise us beyond our expectations. The unpredictable climate on one side and accelerating scientific development on the other give us the scope to identify the best use of science in this context. This

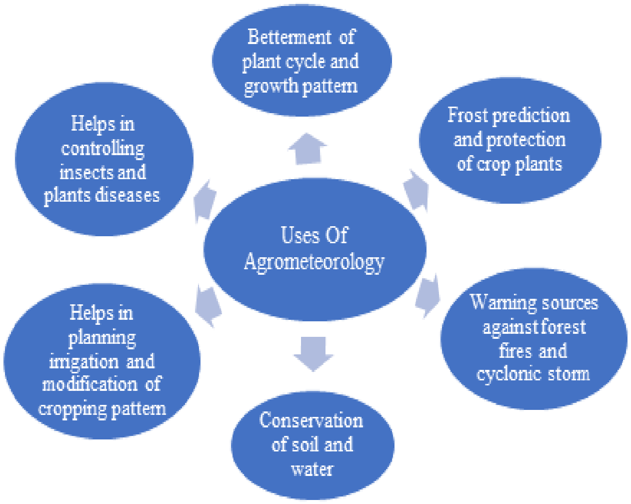

Figure 2. Uses of agrometeorology.
Source: Elaborated by the authors.

demand for an intervention using AI to decide the weather pattern and suggest modification in harvesting can be called agrometeorology. Agrometeorology helps us detect, treat, and mitigate externalities in agriculture, where the study is essential given the growing climatic and other plant-oriented diseases.

Michel frere[7], a senior agro metrologist from Harvard, defined agrometeorology as a "*science which aims at applying meteorological knowledge to the improvement of agriculture*". According to the author, "*this can be done in two ways: Firstly, by creating the best conditions to enable the crops to utilise as well as possible the climatic factors with are favourable to the production of organic matter, secondly, by looking for ways to avoid or to reduce the direct or indirect adverse effects of metrological phenomena which are harmful to crops, such as droughts, frosts, hail. This also includes the fight against crop diseases, the evolution of which is often influenced by weather conditions*". Some of these circumstances of the use of Agrometeorology are shown in Figure 2.

4.1 Present Agrometeorology Initiatives in India and Brazil

4.1.1 Brazil

According Caramori *et al*. (2002), in Brazil there are agrometeorology centres supported by the state governments, by the federal government, and cooperatives of farmers that operate networks of meteorological stations. For instance: the government centres are in São Paulo (SE), with the Campinas Agronomic Institute and its Integrated Information Centre for Agriculture, and a network of mechanical and automated weather stations, supplying water balance and maps of agrometeorological variables. In the South region, the Agronomic Institute (IAPAR) and the Meteorological System, both in Paraná; the Agricultural Research Corporation (EPAGRI) in Santa Catarina; and the State Agricultural Research Foundation of Rio Grande do Sul also manage networks of mechanical stations and automated stations, with daily/weekly updates and forecasts available on their websites. In Goiás (CO), the Meteorological System operates a network of automatic stations with satellite transmission and data display on its home page. For Ceará (CE), the State Meteorological Foundation has a network of automated rainfall stations supporting regional irrigation and subsistence agriculture projects, especially in severe drought. The National Institute of Meteorology has a network of mechanical stations distributed throughout the country, providing daily forecasts on weather conditions, thematic maps of temperature, precipitation, evapotranspiration, and water balance, among others. The National Institute for Space Research (INPE) supports a network of automated stations with data published on its website.

Many other research institutions and companies try to obtain meteorological information to help with production conditions in agriculture. But these experiences are dispersed and sometimes not organised to find small properties in different regions, biomes, and climates. Like India, Brazil has a continental dimension. Many farmers in remote areas need adequate internet access or learn how to handle this information. It demands more significant support from governmental research institutions.

A concern that must be kept in mind is the power relations that can be established by using artificial intelligence and the gaps that can be generated between the various publics of the agricultural sector. The importance of artificial intelligence is not questioned here. Still, there is a concern about democratising access to data so that the positive impacts of using innovative technologies can be leveraged to minimise asymmetries.

From a technical point of view, there are the so-called agriculture 4.0 and now agriculture 5.0, to which various data technologies are related, including the 5G internet. In possession of the Brazilian reality, large landowners responsible for the so-called agribusiness, focused mainly on commodities for export, can more easily benefit from these innovations, with greater access to data technologies developed by start-ups, for example. The question is: how can family farmers located in areas of the Brazilian semiarid region, with difficult access to the internet, have a lower level of knowledge of the tools and with a governmental structure of rural extension weakened by the reduction of resources destined to them in recent years, can benefit from these advances?

Another issue that should be highlighted is that the mix of data technologies involved also raises concerns about the disappearance of humans' role in using artificial intelligence as if humans were becoming obsolete (Bronson, 2022). We point out in this article that we may be facing different contexts of applicability of artificial intelligence, whether within agrometeorology or not. In family farming, artificial intelligence applied to agrometeorology arrives as a complement/help in the rational use of scarce resources, especially considering the need for water management in the semiarid region.

4.1.2 India

In India, evidence of agrometeorology can be traced back to 1945 when the weather conditions were addressed on the radio to the farmers making the accessibility to the information included. As we get modern, where technological influence takes place, the accessibility cost to such information becomes higher. At present, the government has made efforts to establish District agrometeorology advisory centres, but the efficiency of its operation could be better. Keeping the benefits that agrometeorology could bring to the farmers in both countries, the government should implement policies enabling small and medium farmers to access the benefits.

Although at present, the ministry of earth science's initiative, in collaboration with the Indian meteorological department, the state agricultural university, and the Indian council for agricultural research, introduced a scheme called Gramin Krishi Mausam Sewa. "*It issues crop and location-specific weather-based agro advisories for the benefit of the farming community. The Agro-meteorological Advisory Services (AAS) under the GKMS is operated to prepare biweekly weather-based bulletins. The information is transmitted through multimedia channels and SMS to help farmers plan farm operations accordingly*"[8]. Apart from this initiative, institutional-level efforts have been taken to forecast the weather for the consumption of the farmers. Still, there needs to be a specific approach in this regard on a Pan India basis. The national mission for sustainable agriculture plans on these side-lines to implement the idea of precision agriculture and agrometeorology services. However, the benefits of the same could be visible in the years to come. India's district agromet advisory services supply weather forecasting services for farmers. Still, they do not give any AI-based data services where they can access data to plan irrigation, etc.

5. Model of AAUIs (Agromet Artificial Intelligence Units)

5.1 Accessibility Constraints Faced by the Farmers

Taking Brazil and India into consideration, the countries have distinct weather patterns, crop preferences, and market accessibility, but they found common ground in accessibility to modern technologies in agriculture. Large farmers access technological benefits in both countries, making agricultural infra development non-inclusive. The efficient way to make this infrastructure accessible to small farmers is to strengthen the government's implementation strategy. The main challenge is to mobilise resources, strengthen institutions and create innovative mechanisms for implementing policies.

The model of AAUI helps the three-tier system of government to plan and execute the model, enabling the farmers to access the AI service's present constraints.
The constraints that the farmers undergo in accessing are the infrastructure cost. We know that most farmers in India and Brazil are small and medium farmers who need access to basic support like finance and other essentials to practice agriculture. This is where the government should play a role as a facilitator in accessing the infrastructure.

5.2 Agromet Artificial Intelligence Units (AAIUs)

India and Brazil are countries with a strong policy planning strategy but with a weak execution strategy.

This model of AAUI helps the three-tier system of government to plan and execute the model, enabling the farmers to access AI services. As mentioned in the earlier discussion on accessibility, government intervention with cooperative governance can effectively address the issue of non-inclusiveness in accessing this infrastructure. Therefore, to make the infrastructure accessible to all farmers irrespective of their land holdings, the government should own the infrastructure and provide access through the hub and spoke model, where satellite hubs are created, which collect the data and spokes, which are regional centres that provide the information(data) and the infrastructure for the consumption of the farmers. The work process of the model is explained later in the paper. The model is introduced in the country as either a central sector scheme or a centrally sponsored scheme.

5.2.1 Blend of a Top-Down and Bottom-up Approach

The scheme is assumed to be bottom-up (Figure 3) and blends top-down (Figure 4) approaches; the model assumes an ideal political scenario and cooperative governance between the central and regional governments. The model takes a bottom-up approach in terms of planning and a top-down approach in terms of execution. The bottom-up approach is planned from the grass root level, knowing the need from the farmer's point of view, followed by the specialist and technicist opinion for framing the policy.

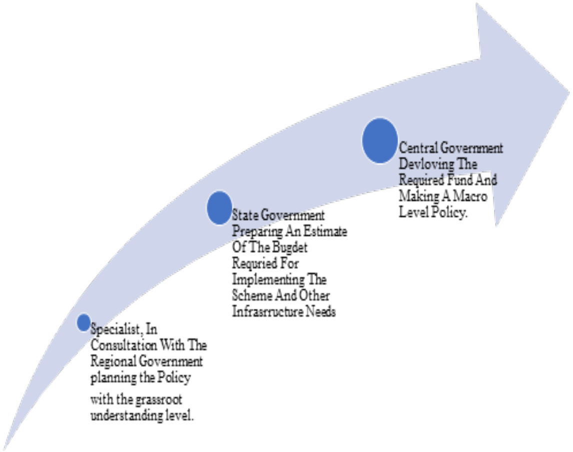

Figure 3. Bottom-up approach to planning.
Source: Elaborated by the authors.

The policy plan starts with a specialist body with the regional government's consultation, understanding the infrastructure's grassroots level need, preparing a report, and sending it to the state government. The state government, which has a better understanding of the region, will prepare a budget to implement the scheme and install the infrastructure. The central government checks the requirement and then prepares a PAN India scheme for the farmers. The bottom-up approach's primary purpose is to help us identify the grass root level requirement and make the policy Tailor-made for the regional beneficiaries. If the region does not require specific infrastructure, as its crops have a counterproductive natural advantage over the infrastructure, then the intended infrastructure may not be needed in that region. This overlapping or unwanted installation of technologies can be avoided through his approach.

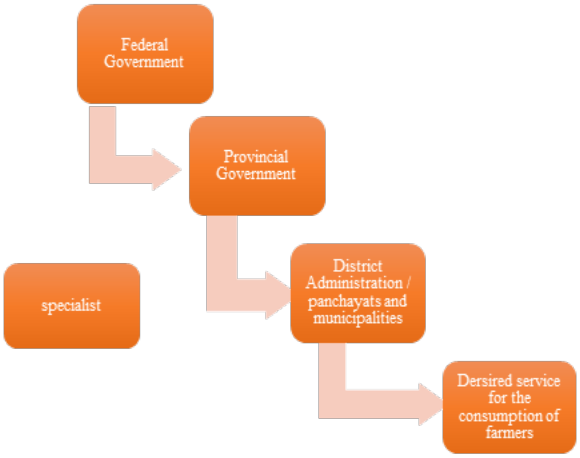

Figure 4. Top-down approach of execution.
Source: Elaborated by the authors.

After the scheme's planning, the central government devolves the fund to the respective state government and the features of accessing the scheme's infrastructure, like illustrated by Figure 5 and Table 2. The state government will devolve the funds and responsibility to implement to the regional authority. The state government will outsource a technical specialist who will help with the operation and maintenance of the infrastructure in the respective region.

Table 2. Hub and Spoke Model.

Hubs	Spokes
She created and located strategically within the region under the surveillance of the district administration.	Created and deployed strategically within the region under the surveillance of the municipal government.
Collects information from the Satellite and transfers the data to the spokes with region specificity	Collects and interprets the data from the hub and simplifies it for the farmers' consumption.
They are managed by the specialist private player whom the state government have outsourced the services.	They are managed by the scientist or the private player to whom the services are outsourced.
	It will have all the AI technologies required for sustainable agricultural practices.
	Will capacitate the farmers with the necessary help to practice and access the infrastructure

Source: Elaborated by the authors

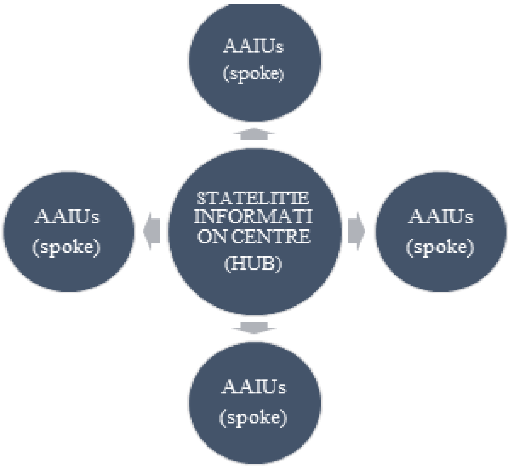

Figure 5. Hub and Spoke Model.
Source: Elaborated by the authors.

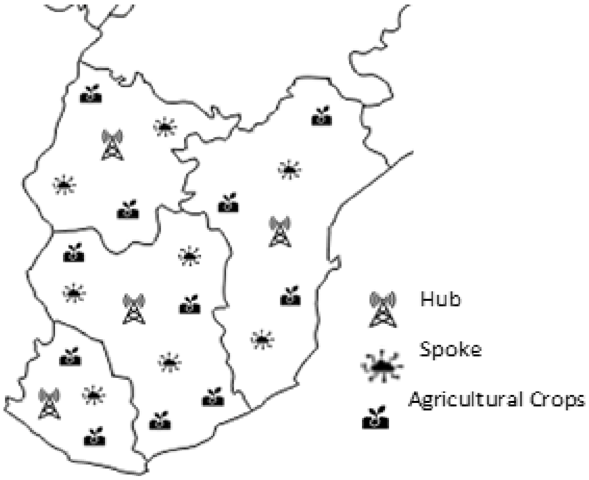

Figure 6. Location of the Hub and Spoke post introduction of the scheme.
Source: Elaborated by the authors.

The spokes are the AAIUs, which supply the information required for the farmers to practice sustainable agriculture. The AAIUs will also contain the necessary infrastructure, such as access to drones and UAVs for the farmer's consumption in that region. The farmers will use this infrastructure with the help of this mechanism in the unit (Figure 6). All the farmers, irrespective of the land holding, will have access to this regional infrastructure for their respective farm use. The teams will also instantly predict the weather with the help of data from the hub through satellite and provide that information to farmers in the region to plan their irrigation strategically, thereby reducing the water consumption for irrigation. This method can also be followed for the fertilisers and other organic chemicals required. The spoke will also provide the information needed to use AI in the region for agricultural practices. This will help farmers detect, trace, and prevent non-unstainable farming practices.

6. Conclusion

Rapid technological changes, environmental and social problems and agricultural crises demand new ways of facing challenges in contemporary agriculture. These forms are associated with sustainability, despite all conceptual, political, ideological, and power disputes inserted in this idea. Artificial Intelligence (AI) appeared as a tool for achieving sustainable agriculture, but it is known that technologies and AI cannot be applied everywhere in the same way. A look at their adaptations to local conditions is required. Given this challenge, precision agriculture and agrometeorology were cited as technical scopes that can be associated with AI, supplying the background to connect production platforms. The large amount of data generated requires model-based decision support systems that collect, interpret, plan, and disseminate information to the end user. For the producer to be engaged, it is necessary to have sources, training and service providers that support him. The process is associated with a technical, socio-economic, and cultural dimension (including how farmers mobilize, think and practice agriculture in different parts of the planet).

Brazil and India are two countries that present challenges regarding the accessibility to this technology in the context of small agricultural production. It is argued that one way to make this infrastructure accessible is to strengthen the government's action strategy. Seeking to provide elements for the debate, a model was shown, aiming to construct the infrastructure of digital agriculture and associated technologies accessible to all farmers. To do so, the government must have the infrastructure and provide access through the hub and spoke model, where satellite hubs are created that collect data and spokes, which are regional centres that provide information (data) to farmers. The model assumes an ideal political scenario and cooperative governance between central and regional governments, adopting a bottom-up approach in terms of planning and a top-down approach in terms of execution. It is assumed that all farmers can access the regional infrastructure created to supply producers with information (on climate, soil, and irrigation). To consolidate the strategies worked on, it is essential to think not only from the farmers' perspective but also from the conditions of use of this system (costs, physical infrastructure, distance, knowledge, among others). The idea is to minimize asymmetries and exclusion factors by adopting digital and AI technologies.

EndNotes

[1] Available from: https://www.techiegen.com/artificialinterlligence. Access on 24/01/2023.

[2] Available from: https://gns.com.sa/solutions/ai/#:~:text=AI%20is% 20much%20more%20about,not%20intended%20to%20replace%20humans. Access on 24/01/2023.

[3] Data that can be freely used, re-used, and redistributed by anyone. Everyone must be able to use, re-use and redistribute - there should be no discrimination against fields of endeavour or persons or groups. Open Knowledge Foundation. Open Data Handbook. Available from: https://opendatahandbook.org/guide/en/what-is-open-data/. Access on 26/01/2023.

[4] Available from: https://www.ispag.org/about/definition. Access on 24/01/2023.

[5] Available from: https://www.embrapa.br/busca- de-noticias/-/noticia/3240771/desertificacao- atinge-grandes-areas-do-semiarido. Access: 20/02/2023.

[6] Available from: https://www.embrapa.br/. Access: 02/06/2015.

[7] Available from: https://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?bibcode=1979ESASP1020....3F&db_key=AST&page_ind=0&data_type=GIF&type=SCREEN_VIEW&classic=YES. Access: 10/11/2022.

[8] Available from: https://www.upscsuccess.com/gramin-krishi-mausam-seva-gkms/. Access on 24/01/2023.

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