Technological Intercropping with the Cloud, IoT, and Big Data in Indian Organic Agriculture

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[Abstract] The Himalayan challenges encompassing Indian agriculture at present is the deterioration of soi1l quality, the decrease in quantity and quality of farm produce, the indiscriminate use of agrochemicals and synthetic fertilizers, unattractive price remuneration for producers, exiguous water availability for irrigation, poor post-harvest practices, and unpredictable weather conditions. Corollaries to these appalling situations include growers who are further prone to distress sales, inaccessibility to formal credit, insufficient market intelligence, detachment from mainstream commercial supply chains, bleak information networks, counterfeit agri-inputs, and mediocre crop management practices. When it comes to organic agriculture, there are many hard challenges, as the protocols are much more stringent and unforgiving. Today, organic agriculture should undergo a paradigm shift from being only traditional to being organic smart agriculture (OSA) in which the technological intercropping (TI) is present with various information and communication technologies (ICTs) and digital technologies, like IoT, cloud computing and big data analytics. This would play a key role in maneuvering desirable information and tools, leading to better decision-making and risk management. Making the organic agriculture smart would involve using the latest high-yielding agricultural technologies coupled up with the value-based technological interventions for improving agricultural productivity and sustainability, all the while remaining globally competitive and environment friendly.

However, given the technological complexities and asymmetry in information networks, small and marginal farmers may not be able to comprehend or come on this platform single handedly; therefore, the role of farmer-based organizations like farmer producer organizations (FPOs), farmer clubs, NGOs operating in rural areas, SHGs, rural formal credit institutions (RFCI), including micro finance institutions (MFIs), crop insurance service providers, panchayat bodies, post offices, certification bodies, etc., will be absolutely critical to strategize and execute the entire game plan. The author envisions a CONSORTIUM DRIVEN MULTIPLE STAKEHOLDER MODEL (CDMSM) for providing these analytics services to the rural diaspora in a customized manner. The idea is to utilize the existing infrastructure available in rural/rural town areas by technologically upgrading them for reaching out to the organic small and marginal farmers. Hence, this would be a cost-effective and faster means to educate and coach the organic grower community. Further, the rural unemployed youths can be trained to act as infopreneurs, and they can be employed with the above-mentioned stakeholder bodies for installation of sensors and proper dissemination of information. Again, the possibility of carbon credit can be worked out, as well as once the technological intercropping takes a concrete shape as the data and information collected integrated with the upgraded infrastructure can be used to do the carbon audit, credit/debit, and trade.

[Keywords] ICT, analytics, big data, internet of things, IoT, cloud computing, organic agriculture, smart agriculture, intercropping infopreneurs

Introduction

As stated by the International Data Centre (IDC, 2018), the global data sphere will grow from 33 zettabytes in 2018 to 175 zettabytes by 2025. According to FiBL and IFOAM Organics International (2020), global organic agricultural land accounted for over 71.5 million hectares (including in-conversion) with 2.8 million producers in 2018. The organic market stands at almost 97 billion euros in 2018. Organic agriculture is bound to prosper owing to growing concerns on climate change, the global shift in dietary patterns, an increased awareness of consumers, the increase in lifestyle diseases, dedicated Government emphasis on nutritional safety and environment, etc. The present time demands that deviating from traditional organic agriculture, India should advocate organic smart agriculture, where the technological intercropping (TI) becomes a critical feature for improving agricultural productivity and sustainability. Starting from the targeting of large farms, this can percolate to the small and marginal farmers and semi-medium farmers, making them effective partners in the mainstream value chain.

With the world producing more data than ever before, it becomes essential to derive meaning and purpose out of it. Big data does that, and with IoT, it becomes easier to communicate among enabled devices on a real-time basis, which further reduces decision-making time and helps in solving problems. Cloud computing helps by providing storage, applications, software, and other tools on a customized basis for optimum utilization of resources in a cost-effective and efficient manner. Hence, all the three technologies and their applications can't be seen in isolation; they have to be amalgamated under the organic smart agriculture scenario. Also, the system infrastructure needs to be flexible enough to accommodate future changes in technologies so that resources and time can be optimized.

As reported by *Markets and Markets* (2019), the market size of analytics in agriculture was pegged at US $ 585 million in 2018, which is expected to reach US$ 1236 million by 2023 with a CAGR of 16.2%.

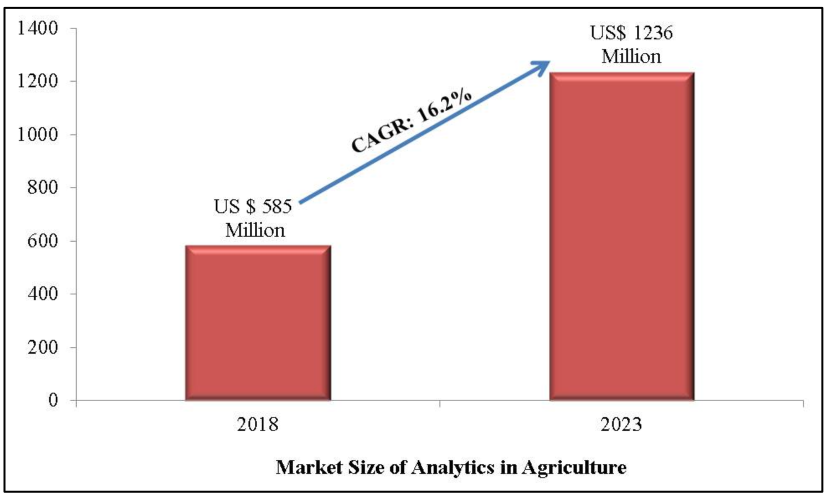

Figure 1. Market Size of Analytics in Agriculture

IoT can help in improving organic agriculture in various ways. The installed sensors can help in generating data related to soil properties, crop growth, weather, irrigation efficiency, equipment efficiency, etc. These data can help in better crop management practices, reduce risk, proactively chalk out post-harvest practices, improve quality of end produce, increase productivity, create better maintenance of quality standards, as per the Internal Control System (ICS) and the National Policy on Organic Production (NPOP) , etc.

These data can be stored and integrated using various applications available using the cloud network. Data acquisition tools, such as wireless sensor networks (WSN) and radio frequency identification (RFID), can also be integrated with cloud computing applications for monitoring temperature, humidity, soil properties, crop growth, etc. Cloud computing services like storage can go a long way in storing huge amounts of data generated by human and machine activity. The data this generates can be made meaningful and purposeful by passing it through the big data analytics system. Big data would help in analyzing the structured and unstructured data, thus becoming a benefactor in monitoring trends, tracking supplies, performing risk assessment, optimizing performance levels, and making correct marketing decisions.

Under the organic agriculture scenario, the information requirement for various groups of farmers will be different based on land holding and aspirational levels. Also, the segmentation of farmers based on the technology requirement becomes essential in coming times, as we see more and more companies getting onto the online mode and e-commerce becoming the cynosure. Thus, the author suggests a consortium-based multi-stakeholder model (CBMSM) to accommodate the technological intercropping and provide the most important agricultural input in the form of information to bridge the gap in the present organic agricultural system.

Internet of Things (IoT), Cloud Computing and Big Data Analytics

As reported by the Pew Research Center (2019), in 2017, the unique mobile subscribers base, globally, was 5.0 billion (a penetration level of 66%), out of which 3.7 billion in the developing markets. It is expected to reach 5.9 billion (CAGR of 2.1%) in 2025 with a penetration level of 71%. A median of 37% own smartphones in the emerging markets.

Internets of Things (IoT)

IoTs are objects that are interrelated and interconnected in a network over the internet and are meant to collect and exchange information/data without human intervention. These objects include mechanical and digital devices laced with sensors, software, and other technologies that can communicate over wireless networks. Diagrammatically IoT ecosystem can be represented as follows in the graph.

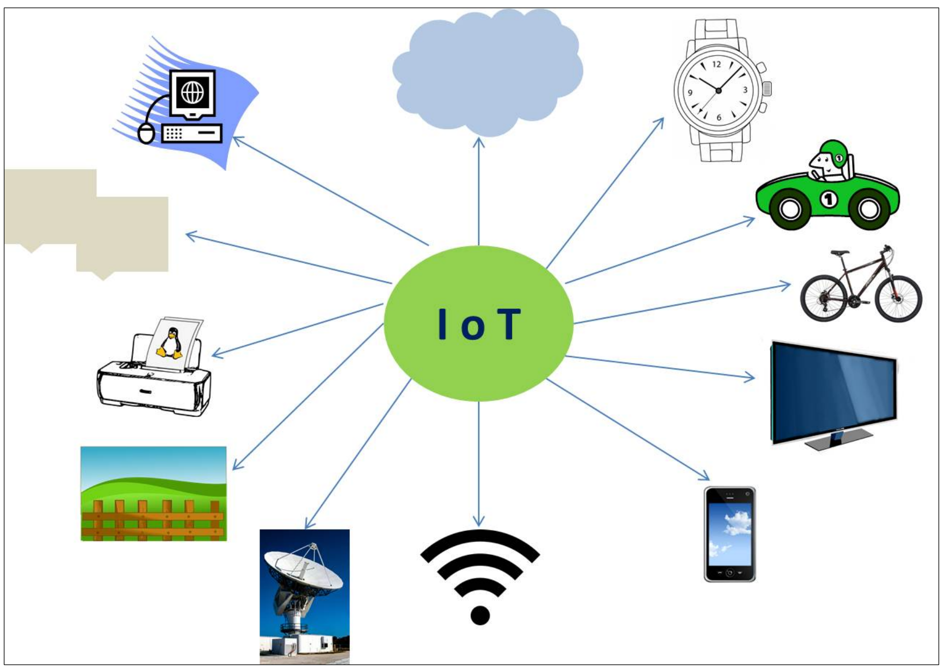

Figure 2. IoT Ecosystem Overview

The Application of IoT in Organic Agriculture can be described as:

ON Farm. Sensors can be deployed for gathering data on soil properties, temperature, humidity, wind direction and velocity, soil fertility status, pH level, crop growth, irrigation requirements, etc. These sensors can be installed on farms, greenhouses, agriculture machinery, etc.

OFF Farm: Sensors can be put in warehouses, cold storage unit, transportation system, etc. **Sensors** like Optical Sensors, Location Sensors (GPS), Electrochemical Sensors, Mechanical Sensors, dielectric soil moisture sensors, parrot sensors, spruce sensors, Koubachi sensors, etc., can be used as necessary.

Drones (ground based or aerial) can be used to provide pictorial and aerial mapping about current status of crop growth, monitoring of progress, spraying requirements, water requirements, assessment of soil/field, etc.

Data transfer methodology, depending on the distance, the can be designed, like near field communication (NFC), radio frequency identification (RFID), Bluetooth low-energy (BLE), low power wide area network (LPWAN), etc.

The benefits IoT can be listed as follows:

- By monitoring the moisture level, irrigation activity can be planned, leading to less waste and improvement in water use efficiency.
- Likewise, by monitoring the fertility level, application of fertilizers and other nutrients can be planned in an accurate manner, leading to improvement in fertilizer use efficiency.
- In greenhouses, automated multiple sensors and systems can adjust the conditions for favorable crop growth without human intervention.
- Real-time information on crop growth can help in understanding the crop health so that farmers can timely correction measures. It also helps farmers in better planning harvest and post-harvest activities.
- The accounting features in the IoT system can help farmers understand the cost benefit ratio of their returns on investment and improve the ways in which they manage their farms.
- The on-farm application of agricultural inputs and the growing methodology gets registered in the IoT system during several stages of crop growth, which makes it easier for ICS agencies to maintain digital diaries and for the certification agencies to verify and validate the data/information.
- Real-time monitoring of crop growth stages and that lead to devising the management practices that help in improving productivity and quality, thereby fetching premiums in the market, especially for organic products.
- Again, it helps to take care of the environment by ensuring the application of water, fertilizer, nutrients, etc. and done in the most judicious manner.
- In fact, any of the production factors on the farm can be suitably optimized for attaining higher productivity and sustainability.
- Timely understanding of weather patterns, pest and disease status, moisture, temperature and humidity helps in cutting down the risk considerably and results in better cost management. It also helps farmers to make better decisions on crop selection and crop rotation practices.

Cloud Computing

Cloud computing refers to a share-pool arrangement whereby computing resources, like servers, storage, and applications, be used on an on-demand basis over the internet. This means the user does not have to use his/her computer's hard drive and can access the cloud network application through the internet.

With reference to Arron Fu (2017), cloud computing models (depending on service provided to the clients) include infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). This stacked format provides services for different sets of users, like application developers, end users, etc.

Again, on the basis of deployment, loud computing can be public, private, and hybrid. This gives individuals or organizations options to customize according to their needs and pay for only the type and length of the service, thus making it cost-effective. Since the services are available through the internet and enabled devices, it provides convenience for users. Figure 3 illustrates the various models of cloud computing based on services and deployment.

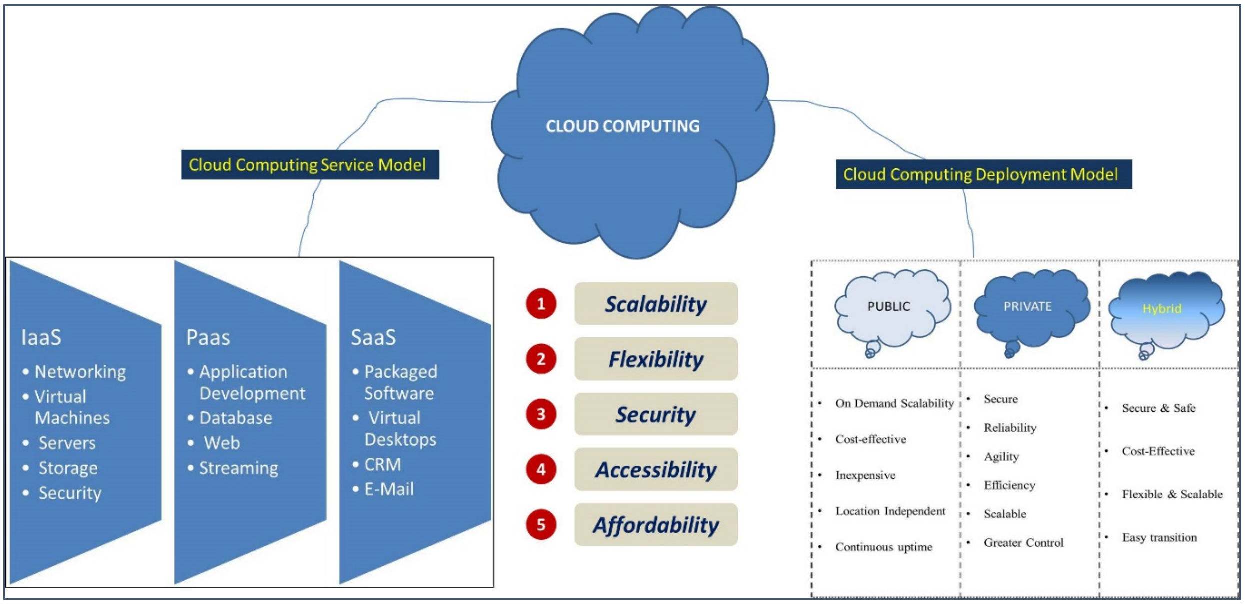

Figure 3. Models of cloud computing based on services and deployment

Public Cloud, as the name suggests, provides services on a network for public use. It is location independent, so any individual or organization does not have control on the infrastructure.

Private Cloud offers more security and is meant for one organization where the usage is on an exclusive basis. This is apropos for organizations requiring data security management, such as government agencies.

Hybrid Cloud offers both the advantages of public and private clouds; some of the applications that require high security can be availed through a private cloud, and those which can be managed without much security can be availed through a public cloud. A hybrid cloud offers much flexibility and security.

Other customized clouds include the community cloud, the personal cloud, etc. The idea is to make the technology as user friendly as possible without compromising on security features and authenticity. The applications and storage services hold the key when we talk about the organic agriculture scenario. Further, based on the need, various stakeholders can opt for various forms of clouds to ensure proper sharing and security mechanisms.

The author envisions the use of the organic farming as a service (OFAAS) pulpit for providing exclusive application, storage, networking, and other need-based services to stakeholders under the cloud computing service model.

The benefits of cloud computing in organic agriculture include:

- Farmers can undertake crop growing plans as needed by the supply-demand dynamics and trends.
- Stored agricultural information can be used by various users anytime, anywhere.
- Perishable, non-perishable, and semi-perishable harvest items and their supply chain can be managed effectively.
- It can greatly enhance the farmer's knowledge of various aspects of farming and support systems.
- Land data, soil data, field data, etc., can be used by policy makers (through public cloud) to frame customized policies for benefiting farmers.
- An accurate databank can be created for better management of micro and macro factors.
- The organic system's stakeholders can pick and choose or switch from/between the range of services and pay as per usage, thereby optimizing the use of resources with cost-effectiveness.

- The historical data can be of great use for ICS and certification agencies for providing organic certification of farm and produce.
- Agri-input companies can have nearly precise forecasting based on real-time and stored data availability.
- Customers can get an idea on the veracity of the products they are consuming. This is particularly important when it comes to organic products.

Big Data

As Figure 5 suggests, big data subjects the data/information, whether structured or unstructured and collected from various sources, to analysis by using several tools. Post analysis, the data provides meaningful and purposeful insight into the entire scheme of things, helping to effect faster and more effective decision-making or problem-solving.

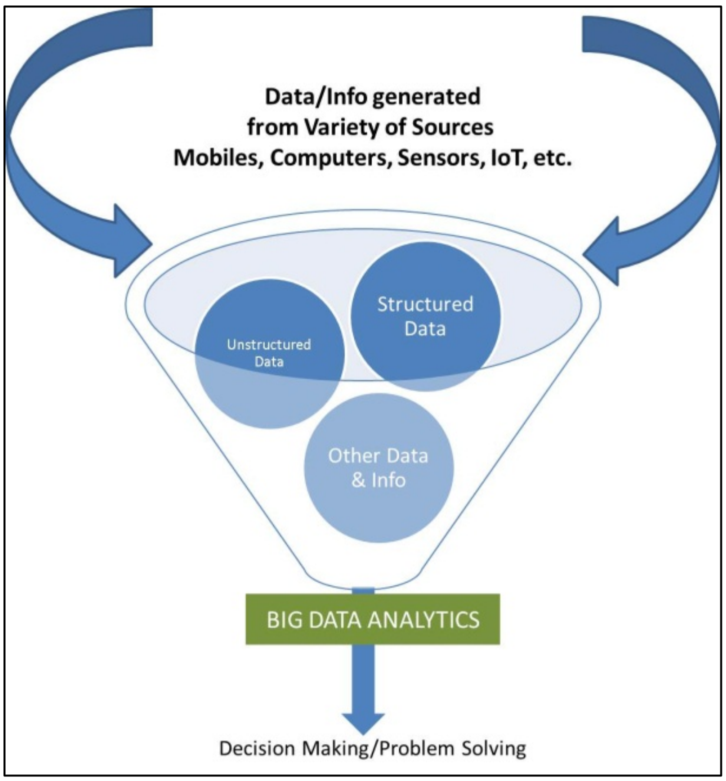

Figure 4. Big Data Funnel & Decision Making

The characteristics of Big Data (Five V's) shows in the follow figure.

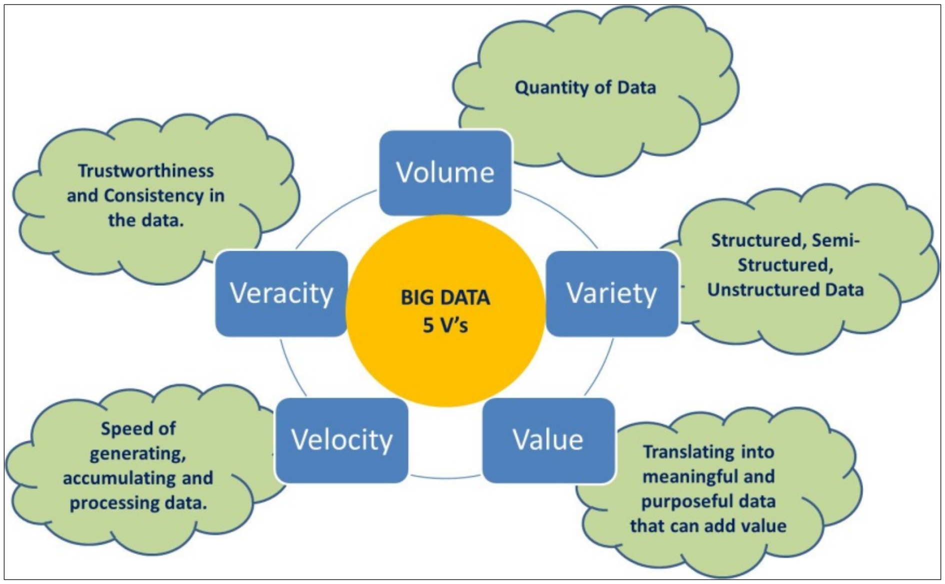

Figure 5. Five Vs of Big Data

Only a huge volume of data can be classified as big data. Again, the sources of data can be multiple and, hence, the speed with which it generates, accumulates, and is processed represents the velocity of big data. The nature of data is heterogeneous and can be structured (proper length and format), semi-structured (e.g., log files and semi organized data) and unstructured (not neat in terms of format; unorganized) and that represents the variety of big data. The trust and consistent factor are important in big data, as it leads to proper processing, analysis, and meaningful representation; this forms the veracity. Now, the entirety big data should add value and be useful, meaningful, and purposeful. Without value, the other V's are meaningless.

The Benefits of Cloud Computing in Organic Agriculture include the following:

- It greatly enhances the decision-making power of farmers, as it provides information on weather patterns, market trends, water cycles, etc.
- It helps in making a nearly accurate forecasting of crop yields, thus reducing the chock for farmers and other value chain participants.
- By proper analysis of structured, semi-structured, and unstructured data, it can be instrumental for government bodies to proactively plan the import-export strategies, disaster management plans, agricultural policies, checking for hoarding by traders, etc.
- The behavioral and psychographic analysis of the farmers can help better market agricultural products .
- This would help the agricultural scientists to design products and agronomic practices at the local level.
- Proper mechanization and usage of semi-processing machineries can be charted.

Consortium Driven Multiple Stakeholder Model (CDMSM)

Under the cloud computing, big data analytics and IoT concepts, the organic agricultural sector would undergo a multifold and multilayered transformation. The challenge would be to transfer the right information at the right time at the right place. For this, the existing infrastructural capabilities existing in the rural space would play a pivotal role in installing, accommodating, disseminating, and customizing information solutions for the organic growers' diaspora.

Since most of the farmers in India are small and marginal, having low investment and risk-taking ability, it is suggested a cluster approach be taken to organize the farmers and register them at various kiosks. The physical infrastructure of these kiosks may not be created afresh; rather, the existing infrastructure, like post offices, panchayat offices, agricultural retailer shops, NGO offices, rural formal credit institutions such as banks and MFIs, farmer producer organizations (FPOs), etc., can be used to collect and disseminate information. The concept of inforpreneurs is being recommended; in it, the rural educated youth can be enrolled and trained for installing the sensors, collecting the data, and customizing according to the farmer requirement. These Infopreneurs can be dedicatedly engaged/employed at these kiosks. The system would be centralized so that a farmer may obtain information from any of the kiosks and not necessarily where he is registered. The inforpreneurs would also trigger and register other value chain participants, like transport, warehousing, cold storages, traders, etc., so that the entire process becomes automated. It would also help the associated value chain stakeholders to proactively plan the inbound and outbound operations leading to better customer satisfaction.

The idea is to create a favorable ecosystem where the organic smart agriculture systems can actually become smart and proactive by using recent ICTs without making much change in the existing infrastructural levels. Through proper knowledge and skill upgradation, the mechanism can be set on rolling mode. The revenue can be generated in the form of service charges. The cost of using the digital infrastructure can be embedded in the government policy itself and can form the part of various schemes like RKVY, PKVY, NFSM, etc., through direct benefit transfer (DBT). The requirement for information is different for diverse sets of farmers and depends on their land holding and aspirational levels. This paper tries to map these perceptions based on the land holding and risk-taking capacity of the farmers; further, it takes a cluster approach to do market/farmer segmentation based on information.

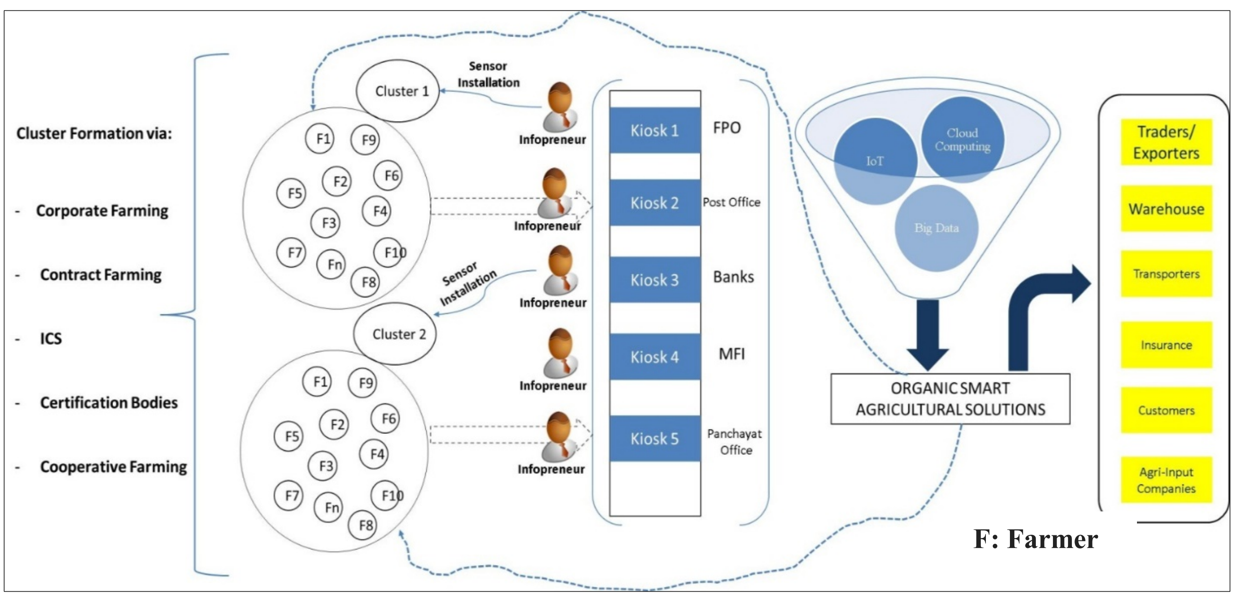

Figure 6. Pictorial Illustration of Consortium Driven Multi Stakeholder Model (CDMSM)

Consortium Driven Multi-Stakeholder Model (CDMSM)

The CDMSM model is explained in Fig 6. The cluster of small and marginal farmers can be formed through corporate farming, cooperative farming, contract farming, ICS, or certification bodies. These clusters would get themselves registered at any of the nearby kiosks. These kiosks can be at post offices, banks, MFIs, etc. The inforpreneurs will act as interface between clusters and kiosks. They will install sensors in the farmer clusters and thereby help in collection of data. These infopreneurs would add on the various tools via the internet to feed, analyze, and make meaningful representation of the structured and unstructured data. Several tools of communication, like SMS, radio, etc., will be used to disseminate proper information at the right place at the right time in an automated manner. The other interested value chain participants, like agri-input companies, warehousing agencies, transporters, insurance service providers, traders/exporters, and customers can get themselves registered on the kiosk pulpit and, thus, can receive information on a real-time basis for a better decision-making process.

The CDMSM model has the following merits:

1. Better and informed decision-making by farmers with respect to crop/variety/hybrid selection, pest and disease management, water use efficiency, fertilizer use efficiency, harvesting dynamics, post-harvest management, transportation, and warehousing, etc.
2. The traders can plan for aggregation or purchase proactively depending on their requirements.
3. The exporters can access the quality and, beforehand, plan for the coveted purchase of the concerned commodities.
4. Large customers can enter into purchase contract directly with the farmers/clusters.
5. Internal Control System (ICS) agencies can have digital diary maintenance and real-time access to various packages of practices of the farmers. This would make assessment easy and hassle free, which would further reduce the manpower cost and the number of farm visits.
6. Certification agencies through meaningful data representation can understand the provenance and farmer practices, thereby reducing the time taken to complete the certification process.
7. This would also help the government in planning imports or exports and timely communication with the farmers on the expectation of crop selection.
8. State Agricultural Universities and Extension Machinery through the ICT tools can transfer automated messages and rectification protocols to the farmers on a real-time basis.
9. Overall, the value chain risk would subside, leading to fair price realization for farmers, transparency in the system, no hoarding by market participants, precise tracking and forecasting, faster claim settlement by banks/insurance service providers, etc.
10. Rural youth as infopreneurs can be employed for income generation.
11. The organic produce provenance and traceability can lead to greater customer satisfaction, belief, and loyalty, especially in case of specialty foods.
12. This would also lead to disintermediation as farmers/clusters would be better informed about the prices and customers. Also, their negotiation power will improve.
13. The proper usage of the public cloud can also lead to processing updates or certification updates on a global level, leading to direct purchases and confidence built up of the famer clusters.
14. The global organic requirements like NOP, JAS, etc., can also be followed and monitored, leading to production of exportable commodities and handsome prices for the farmers.
15. The policy makers can frame policies based on ground realities that can positively influence the actual beneficiaries. This would also help in tracking the actual inflow of benefits and their effects.

The cluster approach would attach the small and marginal farmers to the mainstream supply chain process, thus helping them to reduce risk and improve monetary realizations. Since the chemical usage can be monitored and restricted under organic agricultural systems, carbon credits through verified audit agencies can be used for further income generation as the data availability is automated.

Conclusion

As per the latest report by Internet and Mobile Association of India (IAMAI) and Nielsen (2019); rural India had 227 million active internet users, which was 10% more than urban India (205 million active users) as of November 2019.

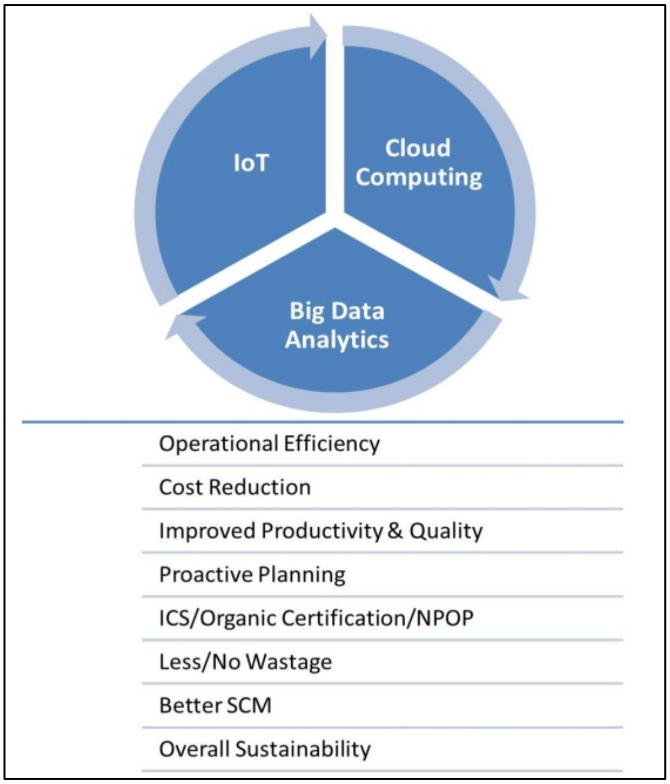

Figure 7. Advantages of using IoT, Cloud Computing and Big Data Analytics in Organic Agriculture

With the increase in penetration of by internet, data's becoming cheap, and smartphones becoming more accessible to rural diaspora, the ICT in agriculture is becoming more prominent for improving agricultural productivity and quality. Under ICT applications, IoT, cloud computing and big data analytics holds great promise for transforming the organic, smart agricultural mindscape and landscape, thereby bringing profitability and sustainability. The envisioned technological intercropping has the necessary capacity to positively influence the entire organic agricultural value chain participants by reducing their risk, improving efficiency, and reducing operational costs, thus ushering in changes in crop management practices, selection of seed and other agricultural inputs, better pest and disease management, improved post-harvest practices, proper planning of warehousing and logistics, favoring environmental sustainability, and minimizing losses.

This concept paper is a genuine attempt to weld the organic agricultural system with the recent developments in ICT with a proper working model in place via the Consortium Driven Multi Stakeholder Model (CDMSM). Further, easier accessibility to data, annexation of digital literacy in the policy framework, inclusion of information as a critical component in agriculture in the government programs, like RKVY, PKVY, NFSM, etc. , and providing the very necessary digital architecture in the rural milieu would pave the way for the digital revolution in organic farming and its associated value chain. This would also help in the generation of rural employment through inforpreneurs and would lead to increased interest of the younger generation in farming.

As the world move towards safe food and nutrition, it would be prudent to involve transparency and provenance in organic agriculture, which can be done by using the already discussed ICT tools. Until and unless a micro view or local outlook is taken into consideration for achieving improved yield and sustainability objectives, the effort will just not be sufficient. The call of the hour is to undertake technological intercropping with IoT, big data analytics and cloud computing under the organic agricultural systems for benefiting the small and medium farmers, along with the entire value chain actors. This will require strong political will and skill to upgrade measures along with the proper digital architecture to translate the entire scheme into a successful proposition.

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