

# Open Systems Science: Digital Transformation and Developing Business Model toward Smart Farms' Platform

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**Abstract**— This paper describes efforts by National Authority for Remote Sensing and Space Sciences (NARSS) to help the Egyptian government to manage and monitor the national projects. We successfully developed a geospatial data sharing portal (NARSSGeoPortal) as part of the government need to build national Decision Support System (DSS). We were able to solve the software development issues as well as the satellite imagery sourcing issues, but the main challenge remains around how to collect complete and correct data from the public about their private businesses nationwide. The most challenging is how to engage the public and encourage the business owners who are the main sources of data to provide the government Geoportal with data about their businesses. It is also challenging to engage the scientists and experts from government research centers into the data sharing Geoportal. Furthermore, it is a challenge to integrate the government research centers with the public businesses' daily operation. The data sharing Geoportal is built for all national projects and government authorities, however, in this paper we focus on the Agriculture authorities and farming businesses where the challenge is how to collect correct and complete data per acre about the seeds, fertilizers, water, pest control and all other farm related data that the satellite imagery does not provide. The goal is to integrate the farms into unified national monitoring, and control system while developing advanced smart farms with the use of Internet of Things (IoT). The proposed collaboration agriculture platform fills the gap between two groups. The first group includes the government authorities, financial institutions, and research centers. The second group includes farmers, supply chain, and agriculture engineers. The platform show how employment can be generated by transforming the national ecosystem. The paper also fills a major gap in industry as well as in academia by providing the first Bluetooth Low Energy

computer aided design tool that will facilitate testing, designing, deploying, managing and debugging of real Bluetooth Low Energy networks.

**Keywords**— Open System Science, Applied Systems Science, System Engineering, Computer Aided Design, Agriculture business model, digital transformation in Agriculture, IoT, smart farming platform,.

## I. INTRODUCTION

There was need to adopt digital tools to assist with better monitoring of national projects. The success of these projects depends on the existence of complete and correct data.

Agriculture plays a pivotal role in sustainable development and is crucial in achieving a suite of Sustainable Development Goals (SDGs) agreed to by the United Nations in 2015 [1].

Sustainable development refers to methods of management that take into consideration the implementation of all aspects of agricultural production, i.e. technical, organizational and managerial requirements of technological processes, both theoretical and practical [2]. Good governance and management of information and policies at all levels are required for long-term sustainability of agricultural sector [3] which considers the economic, environmental, and social aspects of farming [4].

Information about farms, is important in achieving the goals of sustainable development in agriculture. Social media platforms provide a great amount of information to extract and analyze including the ones related to agriculture [3]. Proper use

of social media platforms can revolutionize scientific communication and collaboration [5]. This study proposes a Socio-economic framework for sustainable agricultural, which examines societal aspects (socio) such as the ‘social web’ to be used as a dataset for analyzing the publicly available online content as well as the *economic* concerns such as how employment can be generated by transforming the national ecosystem.

Although smart agriculture technologies and practices are widely available [6], they are not utilized to their full potential because of low levels of adoption by smallholder farmers [7] and most research has been conducted in developed countries rather than developing countries.

In a developing country, smallholder farmers typically do not possess the resources to develop and commercialize a complex value proposition [8]. Therefore, farmers often need to collaborate with other actors, to build a combined ecosystem-wide value proposition [9]. The Egyptian government is seeking collaboration between the stakeholders to build a data sharing platform to support the national development projects. In this project, we took the initiatives and developed a platform to share the geo-spatial information [10] and to design the “National Collaboration for Sustainable Development Spatial Decision Support Portal” [11]. Further details for the geoportal and the DSS are given in [10]-[12]. Because there are thousands of small farms of less than 10 acres, the main challenge was the need for a sustainable flow of complete and accurate data about the national agriculture and farming operations.

The current paper is focused on one core idea (collaboration represented in a platform) defined by three main elements: the value proposition, value creation and delivery and value capture [13]. This paper tries to answer the following questions in the context of a developing country: 1) Who are the stakeholder, key partners, key activities, and what are their main revenue-earning activities? 2) How did the stakeholders collaborated on one platform to form value proposition, value creation, and value capture? 3) What are the effect of the platform on environment and ecosystem, production and sustainability, farm data quality and national decision support, i.e. value creation and value delivery?

This paper proposes smart farming technologies and a methodology on how to fill the gap between the scientific research and realities of farm operation. Figure 1 shows a number of missing links between the government Decision Support Systems (DSS) and the farm operation. The methodology explains how the farm owners will get the help needed for better farm operation and production provided by the government, financial institutions, and research centers. A socioeconomic approach is proposed to create collaborative platform to provide smart farming sustainable development and include number of processes and subsystems as shown in (Fig.1). The objectives of the proposed methodology are to show 1) how employment can be generated by transforming the national ecosystem, 2) how to build the missing links required to connect the farms to the DSS, and 3) how to collect timely, accurate and complete data about the various farm operations

nationwide.

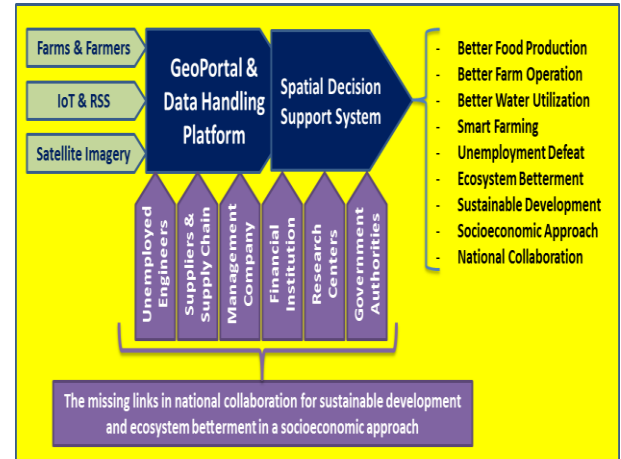


Fig.1 The missing links in national collaboration in Agriculture

There is a need to integrate the decision support systems for agriculture with the Internet of Things (IoT)[14]-[15]. New demands like customer involvement, reiterated development and increased business-orientation raised require new strategies and methods [16]. The available technologies are neither economic nor simple for use by the farms’ owners. That’s why it is more economic, practical, and simpler to introduce skilled agricultural engineers as data handlers between the farmers and the farms from one side, and the smart decision support systems and decision makers on the other side.

The IoT may help in resolving the food safety problem [17]-[19] because it can offer more agile and more convenient management of merchandise, including foods [20]-[21]. The potential of IoT is that information is automatically sent over the network, and embedded applications connected to the internet integrating great computing capabilities and using data analytics to extract meaningful information [22]-[23]. The IoT could help detect where bottlenecks may exist but other technologies may need to be combined, including blockchain which are more responsive to real-time events and can be used to measure volume and timing of supply chains [24]-[25].

Accordingly, the outcome of this paper fills a major gap in industry as well as in academia by providing the first Bluetooth Low Energy (BLE) [26] computer aided design tool that will facilitate testing, designing, deploying, managing and debugging of real BLE networks.

There are many studies have researched on agriculture infrastructure as a case-study approach between supply and demand in the agricultural knowledge infrastructure [27]. In the study by So-In et al. [28] integrated a wireless sensor and mobile system networks with a well-known sensor integration platform toward cloud offloading scalability services via a hybrid architecture used to collect sensing data, such as temperature, humidity, light intensity, and population density, for data analytics and then issuing on-time decisions to adjust the environmental behavior accordingly. Authors in [29] proposed Integrated open geospatial web service enabled cyber-

physical information infrastructure for precision agriculture monitoring. Authors in [30] described a software package called Spatially Explicit Agricultural Dynamics, which investigates agricultural spatial and temporal land-use changes. The study [31] developed smart platform which helps farmers to efficiently manage their greenhouses and to interact with other farmers. Authors in [32] implemented open geospatial infrastructure for data management and analytics in interdisciplinary research. Authors in [33] proposed a Bayesian network method to optimize infrastructure projects by assessing their social contribution. Murakami *et al.* in [34] developed open architecture for the development of distributed service-oriented information systems for precision agriculture based on web services. Tse-Chuan proposed IoT agriculture platform for cloud fog computing that integrated cloud-to-physical networking to improve the computing speed of IoT [35]. Jeppesen *et al.* in [36] developed an open geospatial infrastructure for data management and analytics in interdisciplinary research within the agricultural domain. Bu and Wang [37] developed a smart agriculture IoT system based on deep reinforcement learning. The system integrated artificial intelligence and cloud computing with information techniques to increase food production. Pathak *et al.* developed smart system for determine the allocation of water for farming under any conditions taking into account parameters such as temperature, moisture etc. that were collected by wireless sensors. The system also succeeded in determining the selection of appropriate crops for particular soil [38]. Vincent *et al.* proposed system which help the farmers to assess the agriculture land for cultivation of crops utilizing machine learning algorithm and sensor networks. They assessed the performance of the algorithm with accuracy of 99% for land suitability [39]. Authors in [40] developed knowledge base and multi-agent system for management of agricultural enterprises. Pachayappan *et al.* in [41] developed an IoT based applications for different sectors like oil and refinery, pharma, manufacturing etc. the developed framework succeeded in monitor and control the yield of sugar cane, monitor water level, soil moisture and the cultivation wastages, etc. Guo described an application of Agricultural IoT Technology Based on 5G Network in [42]. Abdallah *et al.* in [43] developed hierarchical-logic mapping and algorithms for optimizing the deployment of wireless IoT for Precision agriculture. The study in [44] presented state-of-the-art of IoT solutions for smart agriculture by identifying the most commonly used hardware, platforms, network protocols and technologies and their applicability in smart farming. Sekaran *et al.* in [45] presented architectural framework for monitoring crops utilizing cloud computing and IoT. Garcia *et al.* summarized the-state-of-the-art for smart irrigation systems which identified the different parameters such as soil characteristics, water quantity and quality etc. They overviewed also the common utilized wireless technologies for irrigation system [46]. Alhasnawi *et al.* in [47] developed a smart system to predict the irrigation requirements of a field utilizing the sensing and detecting of ground parameters like soil moisture, and environmental conditions along with the online weather forecast data. Novák *et al.*

explained how to deploy IoT technologies within agriculture operations with a focus on fuzzy logic in [48]. There are many studies on using IoT in different applications such as in [49]-[51]. But at the moment, there is no known research that provides a solution on how to bring research into reality and get the farmers to benefit from researches [49]-[53].

Furthermore, there is a need for a methodology nationwide build the missing links to fill the gap between research, technologies, and the real farm operation. That's what we are proposing here in this paper as a socioeconomic approach as early contribution for future research. In this phase, we focus on two modules previously proposed in [10]-[12] that are the "experts' consortium" and the "services for the public". Both modules are cloud-based geospatial platforms and facilitate collaboration in a socioeconomic approach. Also, a third module eLearning platform is included to provide the support and training required for all the participants to be certified to provide professional jobs. The framework (Fig.2) contains four areas, a) the farm operation and management, b) GIS Experts' consortium, c) web-based services for the public, and d) Training and support.



Fig. 2 Framework for Sustainable Development in Agriculture & Farming.

## II. CONTRIBUTION TO THEORY

This article presents an open framework which identify the missing links between the government decision support systems and the farm operation. It fills a major gap in industry as well as in academia by providing the first BLE computer aided design tool which facilitates testing, designing, deploying, managing and debugging of real BLE networks. It also presents various business models to show how to connect all partners, customers and key resources in one system and to show the cost structure and revenue streams depending on whom will own the system.

## III. CHALLENGES AND STATEMENT OF THE PROBLEM

During the development, there were some challenges as follows:

*First challenge:* NARSS did not have enough collaboration with the stakeholders or the Cabinet data services which sometimes led stakeholders to build their own systems, tools

and resources to get the information they needed instead of collaborating with NARSS services. Consequently, segregated knowledge was created and became impractical to provide complete national information accurately and in time.

*Second challenge:* Spatial data would be more readable and valuable if requests for information were regulated by guidelines from the stakeholders and the Cabinet when requesting national spatial information. Also, constraints should be taken into consideration if there is a conflict between authorities or overlapping resources because no stakeholder claims ownership.

*Third challenge:* There is a lack of knowledge and agreement on the common standards that should be used and how to impose them on a system. It is similar to challenges in finding the proper way to implement policies within the workflow of a data sharing system. In both cases (policies and standards), we need to create methods and build tools to handle the metadata in a standard way and to transform the policies context into a process.

*Fourth challenge:* There are not enough data to feed the system and the level of accuracy of the collected data must be elevated. The amount of information required will need enormous human resources to collect and make available to the system.

*Fifth challenge:* The current ecosystems became dynamic with a high rate of transformation. The traditional way of building information systems for a static organizational structure is not sufficient anymore and instead requires building a knowledge-based information system that is nimble enough to cope with our continuous changes.

*Sixth challenge:* There are some challenges from the farm side as the farmers have no interest to give data.

The solution is to build a collaborative system that combine these data in one platform

The aim is to identify the data required to enhance food production and irrigation. The challenge here is that because the above areas of interests were not taken into consideration, consequently, we have no idea how it behaves, the collected information became haphazard and there is no way we could build a system based on it.

The solution is to build a network of “smart systems for information gathering” that are smart enough to recognize every elements required to be measured on the level of each farm, each acre and sub-acre and build a network of “smart systems for monitoring and reporting” that are smart enough to recognize the pollution caused by industrial waste, dead animals, fertilizers, polluted air, garbage, detergents dump, Smearing, impurity, quality grades, sandstorm, grasshopper, insects, diseases, and pests. And let’s build these networks of systems smart enough to report on the person or the corporate responsible for such causes.

The network of the smart systems will also be used for management, stimulation, and developing better agriculture system for better food production and irrigation countrywide. We propose to apply the proposed theory and concepts and build a network of human resources that are very close to the farms, the farmers, and the farms’ owners. This network is

dealing with the agricultural associations, agriculture experts, and materials suppliers (for seeds, fertilizers...etc.). So, basically, we can employ the unemployed human resources in gathering accurate information, monitoring the farms, and helping in advising the farmers for the best food production for their farms. The network is also used as interface between the farms needs and the other service providers. This way, we assure having accurate information on the farm level.

#### IV. METHODOLOGY

Most importantly, an ICT-based ecosystem includes individuals who create, buy, sell, regulate, manage and use technology. We believe that rather than building an information system based on the current national development, we should build human structures that get inserted within our ecosystem. Our socioeconomics approach in building the platform constructs a nationwide network of self-employed agricultural engineers who will be the interface between the farms and farms’ owners’ one side and the food supply chain, financing, insurance, research centers, and government authorities on the other side. The engineers are part of the platform and their self-employment costs are covered from fees for supporting and providing managed services for the farms.

Hereinafter the main components of the framework and their details.

Public input is one of the best validation methods [54]. The system should be open to public through web-based applications to gather as much real verified data as possible. No other system can be challenged against one thousands of public subscribers feeding information about their properties, farms, crops, businesses, what they see, what they found, pollution, leaks, bird disease, sand storm, rare species ...etc. Other examples of alerts like program shutdown, overcrowding, and etc.

The goal is to encourage businesses and public users to feed the system with data meaningful to stakeholders to profit accuracy, details, and more metadata. For example, the actual vegetation theme reported by farms’ owners will add a way of improving accuracy that could be used in crop recognition. Reported construction on agriculture land may help in building violation alert-based system. There is a long list of the public interest to report and will be willing to report if the public can find easy way to report.

The complete system is based on using satellite and airborne imageries plus pre-produced maps and spatial layers. We decided to use open source software packages (QGIS, GRASS, and R language) as a combination that have long history and supported by large organizations. The system provides platform to facilitate building management, planning, and monitoring tools. It contains human resources to provide the knowledge and also include hardware, network, software, data, data entry, database, and policies governing data exchange.

When considering the technology to be used for connectivity, Bluetooth Low Energy (BLE) clearly stand out due to its ultra-low power and pervasiveness. Ultra-low power allows sensors to operate for long time. Thus, BLE sensors can form a mesh

network to convey all data gathered to distant gateways installed at the edge of the farm, which on their turn can relay the sensed data to data sinks using cellular communication technologies. Thus, using BLE as the underlying infrastructure precludes the need for installing wires within the farm which could otherwise have impaired the soil and plantations.

#### *A. Units Geospatial services for public*

The framework provides cloud-based services to the public in multi-disciplines like real estate, farming, manufacturing, food supply, transportation ...etc. It is designed so that the citizens will subscribe to the services and build their own profiles. It also provides services for their properties and businesses. The framework also provides a way for public to report on hazards. Public input is one of the validation methods. Citizen participation is one of the best approved techniques [54]-[55]. The system gathers real verified data. The system encourages millions of public subscribers feeding information about their properties, farms, crops, businesses, what they see, what they found, pollution, leaks, bird disease, sand storm, rare species ...etc.

The intent is to encourage businesses and public users to feed the system with data meaningful to stakeholders to gain accuracy, details, and more searchable metadata. For example, the actual vegetation reported by farms' owners will add a way of improving accuracy that could be used in crop recognition from space. Reported construction on agriculture land may help in building violation alert-based system.

#### *B. GIS Expertise Consortium*

It is framework to assemble experts in geospatial information technology from national entities and stakeholders to enrich the knowledge and exchange of experiences toward better geospatial information systems. The framework receives the problems that need a study or a solution, then, request participation in finding solutions and practices. It will provide a good environment to develop open-source software and

solutions to support decision-making and problem-solving at hand. The cloud-based services will present studies, call for participation in a project, and call for modeling similar to the services provided by Freelancer website. Experts will get connected to projects and related resources to provide assistance, develop models and operation scenarios, create analysis method, etc.

#### *C. System Framework Business Model*

We thought about putting a business model for the proposed collaborative framework, but we have to define first the business owner and main stakeholders. For example, the farm is the main customer in all business models. The government could play the role of the business owner but also is a customer for the framework. The research center could play the role of the research provider for all; the government, the farms, the financial institution, and the agriculture engineers. Finally, the engineer, although may work under the government, but they serve the farms, the government, the research centers, and the supply chain. Hereinafter, we are proposing 3 business models where each model is based on who is the owner or providing the service. We excluded supply chain, financial institution, and insurance companies because they are not objective.

- **GOVERNMENT AUTHORITIES**

The government authorities in general and ministry of agriculture in particular shall sponsor and own the platform. Business model when the system owned by government is shown in Fig.3. Also, a third party collection and accounting entity could be employed to provide the administration for all the financial transactions within the farm system operation and mentor the transactions between the vendors, farmers, and financial institutions. The government will gain a) Complete and correct data on the agriculture land and vegetation, b) Better planning for national needs, c) More tax return and licensing income, d) Better water conservation, and f) Creating employment.

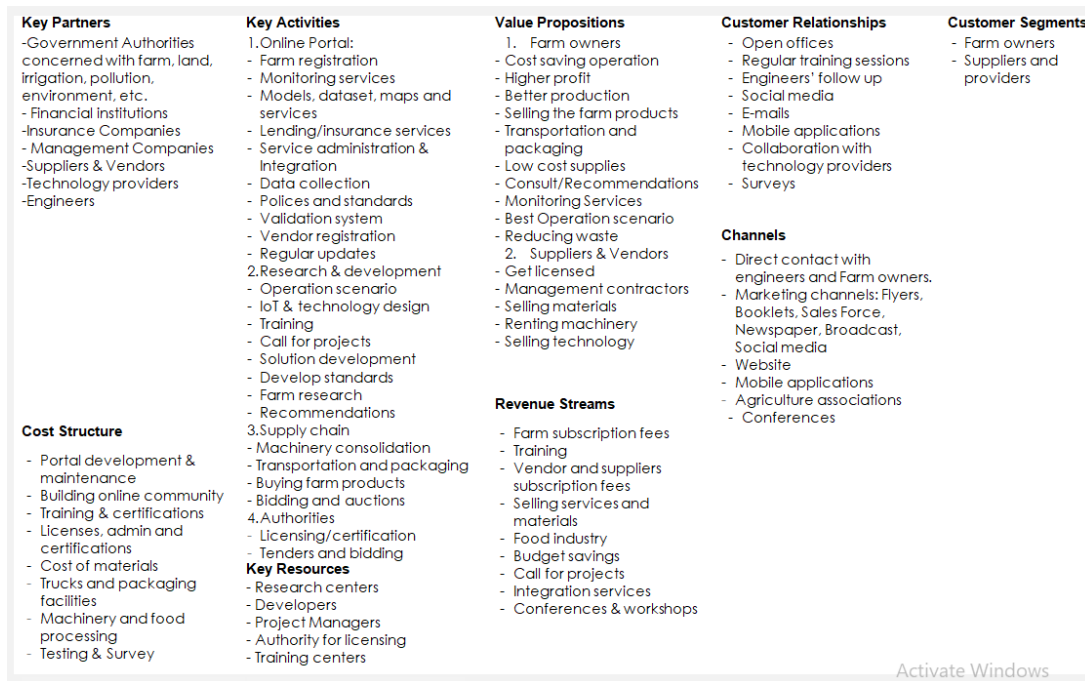


Fig.3 Business model when the platform owned by the government.

• RESEARCH CENTRES

Government research institutions shall collaborate into the experts' platform/portal to develop successful farming scenarios to improve the farm production and create tools to monitor the farm operation. Agriculture Research Centre business model is shown in Fig.4. The focus is on production, quality, and profit per acre. The experts' platform gets connected with the farms through the engineers. Also, the platform receives the farm monitoring feedback and collects the farm data accurately and complete. Eventually, when the platform reach a maturity level to serve large number of farms, the research centers will develop more tools toward implementing more advanced smart farms. The experts' platform will facilitate:

- a) Developing different successful scenarios for a farm,
- b) Building the knowledge base about the model farm and the smart farm,
- c) More focused researches,
- d) Accurate and complete data feedback on applying the researches,
- e) Better management for the research funds in agriculture and farming,
- f) Funds toward producing better cultivation and vegetation scenarios,
- g) Better ways for the knowledge transfer, training, and certification, and
- h) Faster path to build the national smart farming systems and tools.

The change in the Research Centre activities is to build the link to the agriculture engineers by making the farming scenarios available online and build the training and the certification programs for the engineers. The research centers will also build the funnels required to collect data by the engineers about the farms and the farming transactions. Eventually, the platform will reach a maturity level and provide advanced technology smart farming systems nationwide. Also,

the engineers will be experienced enough to maintain and support the smart farms' operation. Ideally, the Ministry of Agriculture should be in charge of the platform. Alternatively, a holding company may be licensed from the government to own and manage the platform. The platform is a profit making business which will be worthwhile for investors to compete to take the license and the ownership.

Demand is driven by government investment in science and technology by creating companies affiliated with major research universities or institutes. These companies will generate revenue by licensing patents and other intellectual property, and some receive grants from government and private sources. These companies will conduct research or apply research findings to develop new products or processes in Agriculture. The company will manage the platform and the collaboration between farms' owners and the services provided by government, financial institutions, insurance companies, supply chain vendors, and research centers. While a legal agreements and contracts will be performed between the company and the other entities, a cloud-based portal will serve the transactions between all parties. Business model when the system owned by the company is shown in Fig.5. Here are some of the company characteristics: (a) Holding company handling nationwide agriculture and farming business, (b) Profit making business rather than nonprofit operation, (c) Provides a structure for farms' consolidation and the farming business, (d) Organizes the licensing process to assure the provision of well-educated and specialized personnel, (e) Provides training to the engineers, the farmers and other participants, and (f) Facilitates the implementation of the successful farming scenarios to the farms.

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
<ul style="list-style-type: none"> <li>-Government Authorities concerned with farm, land, irrigation, pollution, environment, etc.</li> <li>- Financial institutions</li> <li>-Insurance Companies</li> <li>- Management Companies</li> <li>-Suppliers &amp; Vendors</li> <li>-Technology providers</li> <li>- Engineers</li> <li>-Sponsors</li> <li>-International research Organizations</li> </ul>	<ol style="list-style-type: none"> <li>1. Online Portal:                             <ul style="list-style-type: none"> <li>- Farm registration</li> <li>- Monitoring services</li> <li>- Models, dataset, maps and services</li> <li>- Lending/insurance services</li> <li>- Service administration &amp; Integration</li> <li>- Data collection</li> <li>- Polices and standards</li> <li>- Validation system</li> <li>- Vendor registration</li> <li>- Regular updates</li> </ul> </li> <li>2. Research &amp; development                             <ul style="list-style-type: none"> <li>- Operation scenario</li> <li>- IoT &amp; technology design</li> <li>- Training</li> <li>- Call for projects</li> <li>- Solution development</li> <li>- Develop standards</li> <li>- Farm research</li> <li>- Recommendations</li> </ul> </li> <li>3. Supply chain                             <ul style="list-style-type: none"> <li>- Machinery consolidation</li> <li>- Transportation and packaging</li> <li>- Buying farm products</li> <li>- Bidding and auctions</li> </ul> </li> <li>4. Authorities                             <ul style="list-style-type: none"> <li>- Licensing/certification</li> <li>- Tenders and bidding</li> </ul> </li> </ol>	<ol style="list-style-type: none"> <li>1. Farm owners                             <ul style="list-style-type: none"> <li>- Cost saving operation</li> <li>- Higher profit</li> <li>- Better production</li> <li>- Selling the farm products</li> <li>- Transportation and packaging</li> <li>- Low cost supplies</li> <li>- Consult/Recommendations</li> <li>- Monitoring Services</li> <li>- Best Operation scenario</li> <li>- Reducing waste</li> </ul> </li> <li>2. Suppliers &amp; Vendors                             <ul style="list-style-type: none"> <li>- Get licensed</li> <li>- Management contractors</li> <li>- Selling materials</li> <li>- Renting machinery</li> <li>- Selling technology</li> </ul> </li> <li>3. Government                             <ul style="list-style-type: none"> <li>- Training</li> <li>- Low cost supplies</li> <li>- Research Services &amp; Recommendations</li> <li>- Service Administration</li> <li>- Monitoring Transactions</li> </ul> </li> </ol>	<ul style="list-style-type: none"> <li>- Open offices</li> <li>- Regular training sessions</li> <li>- Engineers' follow up</li> <li>- Social media</li> <li>- E-mails</li> <li>- Mobile applications</li> <li>- Collaboration with technology providers</li> <li>- Surveys</li> </ul>	<ul style="list-style-type: none"> <li>- Farm owners</li> <li>- Supplier and providers</li> <li>- Government</li> </ul>
Cost Structure	Key Resources	Revenue Stream		
<ul style="list-style-type: none"> <li>- Portal development &amp; maintenance</li> <li>- Building online community</li> <li>- Training &amp; certifications</li> <li>- Licenses, admin and certifications</li> <li>- Cost of materials</li> <li>- Trucks and packaging facilities</li> <li>- Machinery and food processing</li> <li>- Testing &amp; Survey</li> </ul>	<ul style="list-style-type: none"> <li>- Research center</li> <li>- Developers</li> <li>- Project Managers</li> <li>- Authority for licensing</li> <li>- Training centers</li> </ul>	<ul style="list-style-type: none"> <li>- Farm subscription fees</li> <li>- Training</li> <li>- Vendor and suppliers subscription fees</li> <li>- Selling services and materials</li> <li>- Food industry</li> <li>- Budget savings</li> <li>- Call for projects</li> <li>- Integration services</li> <li>- Conferences &amp; workshops</li> </ul>		

Fig.4 Business model when the platform owned by Research Centre

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
<ul style="list-style-type: none"> <li>-Government Authorities concerned with farm, land, irrigation, pollution, environment, etc.</li> <li>- Financial institutions</li> <li>-Suppliers &amp; Vendors</li> <li>-Insurance companies</li> </ul>	<ol style="list-style-type: none"> <li>1. Online Portal:                             <ul style="list-style-type: none"> <li>- Farm registration</li> <li>- Monitoring services</li> <li>- Models, dataset, maps and services</li> <li>- Lending/insurance services</li> <li>- Service administration &amp; Integration</li> <li>- Data collection</li> <li>- Polices and standards</li> <li>- Validation system</li> <li>- Vendor registration</li> <li>- Regular updates</li> </ul> </li> <li>2. Supply chain                             <ul style="list-style-type: none"> <li>- Machinery consolidation</li> <li>- Transportation and packaging</li> <li>- Buying farm products</li> <li>- Bidding and auctions</li> </ul> </li> </ol>	<ol style="list-style-type: none"> <li>1. Farm owners                             <ul style="list-style-type: none"> <li>- Cost saving operation</li> <li>- Higher profit</li> <li>- Better production</li> <li>- Selling the farm products</li> <li>- Transportation and packaging</li> <li>- Low cost supplies</li> <li>- Consult/Recommendations</li> <li>- Monitoring Services</li> <li>- Operation scenario</li> <li>- Reducing waste</li> <li>- Link between farms and research centres</li> </ul> </li> <li>2. Suppliers &amp; Vendors                             <ul style="list-style-type: none"> <li>- Management contractors</li> <li>- Selling materials/products</li> <li>- Renting machinery</li> <li>- Selling technology</li> </ul> </li> <li>3. Government                             <ul style="list-style-type: none"> <li>- Training</li> <li>- Low cost supplies</li> <li>- Research Services &amp; Recommendations</li> <li>- Service Administration</li> <li>- Monitoring Transactions</li> <li>- Selling &amp; Marketing</li> </ul> </li> </ol>	<ul style="list-style-type: none"> <li>- Regular training sessions</li> <li>- Social media</li> <li>- E-mails</li> <li>- Mobile applications</li> <li>- Collaboration with technology providers</li> <li>- Surveys</li> <li>- Periodic visits and follow up</li> </ul>	<ul style="list-style-type: none"> <li>- Farm owners</li> <li>- Suppliers and providers</li> <li>- Government</li> </ul>
Cost Structure	Key Resources	Revenue Streams	Channels	
<ul style="list-style-type: none"> <li>- Portal development &amp; maintenance</li> <li>- Building online community</li> <li>- Training &amp; certifications</li> <li>- Admin and certifications</li> <li>- Computers &amp; Internet access</li> <li>- Trucks and packaging facilities</li> <li>- Machinery and food processing</li> <li>- Testing &amp; Survey</li> </ul>	<ul style="list-style-type: none"> <li>- Research centers</li> <li>- Developers</li> <li>- Project Managers</li> <li>- Authority for licensing</li> <li>- Training centers</li> </ul>	<ul style="list-style-type: none"> <li>- Farm subscription fees</li> <li>- Training</li> <li>- Vendor and suppliers subscription fees</li> <li>- Selling services and materials</li> <li>- Integration services</li> <li>- Conferences &amp; workshops</li> <li>- Consultation</li> <li>- Marketing and sales</li> </ul>	<ul style="list-style-type: none"> <li>- Direct contact with Farm owners.</li> <li>- Marketing channels: Flyers, Booklets, Sales Force, Newspaper, Broadcast, Social media</li> <li>- Website</li> <li>- Mobile applications</li> <li>- Agriculture associations</li> <li>- Conferences</li> </ul>	

Fig.5 Business model when the platform owned by Research Company

• AGRICULTURE ENGINEERS

The agriculture engineers work on implementing the recommended research centers' scenarios in their local villages. Agriculture engineers' business model in providing farm services is shown in Fig. 6. The engineers are connected through a cloud-based platform and all must be certified to use it. The engineers will contract the farms' owners to increase the productivity and the profitability of the farm. In more details, the engineer will: a) Implement better cultivation and vegetation following the recommended scenarios from the experts who are authorized by the government authorities. b) Coordinate between farming operations, supply chain, government authorities, research centers, and management companies. c) Gets best deals for seeds, fertilizers and other materials. d) Use the portal to report on daily operation transactions and monitoring events, e) Use the portal to receive the recommended scenarios for the assigned farms, f) Reports on any hazards, contamination, and losses related to the

managed farms. g) Represent the farm owner in the front of the other authorities. h) Expediting paper work for the financial applications, purchasing, and contracting, i) Coordinate with the marketing and sales system, j) Coordinate the food transportation and packaging. k) Be an expeditor for 100 farms of 5 acres average size.

In return the benefits for the engineer a) Being self-employed with sustainable income, knowledge, and experience, b) Training and supervision by the experts from the research centers and supported by the government, and c) Licenses and benefits provided by the system. The agriculture engineers will use the best farming scenarios [52],[55] in their implementation. The farming scenarios are developed by the expertise from the government research centers and their cost are already covered conducting researches is part of their mandates.

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
<ul style="list-style-type: none"> <li>-Government Authorities concerned with farm, land, irrigation, pollution, environment, etc.</li> <li>- Management Companies</li> <li>-Suppliers &amp; Vendors</li> <li>-Research centres</li> </ul>	<ol style="list-style-type: none"> <li>1. Online Portal:                             <ul style="list-style-type: none"> <li>- Farm registration</li> <li>- Monitoring services</li> <li>- Models, dataset, maps and services</li> <li>- Lending/insurance services</li> <li>- Service administration &amp; Integration</li> <li>- Data collection</li> <li>- Policies and standards</li> <li>- Validation system</li> <li>- Vendor registration</li> <li>- Regular updates</li> </ul> </li> <li>2. Supply chain                             <ul style="list-style-type: none"> <li>- Machinery consolidation</li> <li>- Transportation and packaging</li> <li>- Buying farm products</li> <li>- Bidding and auctions</li> </ul> </li> </ol> <p><b>Key Resources</b></p> <ul style="list-style-type: none"> <li>- Research centers</li> <li>- Developers</li> <li>- Project Managers</li> <li>- Authority for licensing</li> <li>- Training centers</li> </ul>	<ol style="list-style-type: none"> <li>1. Farm owners                             <ul style="list-style-type: none"> <li>- Cost saving operation</li> <li>- Higher profit</li> <li>- Better production</li> <li>- Selling the farm products</li> <li>- Transportation and packaging</li> <li>- Low cost supplies</li> <li>- Consult/Recommendations</li> <li>- Monitoring Services</li> <li>- Operation scenario</li> <li>- Reducing waste</li> <li>- Link between farms and research centres</li> </ul> </li> <li>2. Suppliers &amp; Vendors                             <ul style="list-style-type: none"> <li>- Management contractors</li> <li>- Selling materials/products</li> <li>- Renting machinery</li> <li>- Selling technology</li> </ul> </li> <li>3. Government                             <ul style="list-style-type: none"> <li>- Service Administration</li> <li>- Monitoring Transactions</li> <li>- Selling and Marketing</li> </ul> </li> </ol>	<ul style="list-style-type: none"> <li>- Regular training sessions</li> <li>- Social media</li> <li>- E-mails</li> <li>- Mobile applications</li> <li>- Collaboration with technology providers</li> <li>- Surveys</li> <li>- Periodic visits and follow up</li> </ul> <p><b>Channels</b></p> <ul style="list-style-type: none"> <li>- Direct contact with Farm owners.</li> <li>- Marketing channels: Flyers, Booklets, Sales Force, Newspaper, Broadcast, Social media</li> <li>- Website</li> <li>- Mobile applications</li> <li>- Agriculture associations</li> <li>- Conferences</li> <li>-</li> </ul>	<ul style="list-style-type: none"> <li>- Farm owners</li> <li>- Suppliers and providers</li> <li>- Government</li> </ul>
<p><b>Cost Structure</b></p> <ul style="list-style-type: none"> <li>- Portal development &amp; maintenance</li> <li>- Building online community</li> <li>- Training &amp; certifications</li> <li>- Admin and certifications</li> <li>- Computers &amp; Internet access</li> <li>- Trucks and packaging facilities</li> <li>- Machinery and food processing</li> <li>- Testing &amp; Survey</li> </ul>	<p><b>Revenue Streams</b></p> <ul style="list-style-type: none"> <li>- Farm subscription fees</li> <li>- Training</li> <li>- Vendor and suppliers subscription fees</li> <li>- Selling services and materials</li> <li>- Integration services</li> <li>- Conferences &amp; workshops</li> <li>- Consultation</li> <li>- Marketing and sales</li> </ul>			

Fig. 6 Business model when the platform owned by Agriculture Engineers



- INSURANCE COMPANIES

The insurance companies normally don't deal with farms. In socioeconomic farming platform, a social insurance will cover the minimum income expected per acre in case of full loss of the session production similar to the employment insurance in western countries. Insurance will cover stolen equipment, fire, fluid, and traditional causes for insurance.

- VENDORS AND SUPPLIERS

Vendors and suppliers are providing the agricultural equipment, tools, supplies, and raw materials (i.e. seeds, fertilizers... etc.). They are required to be registered in the platform and use the supply chain managed by the government. The research centers will provide the standard specifications for compliance.

- FINANCIAL INSTITUTIONS

Usually, banks and financial institution are a bit hesitant to lend the farm owners particularly the small farms. However, the government could facilitate insurance to the financial institutions, mentor the financing operation for compliance, and collect taxes accurately and on time. The government and insurance companies, will give more credibility because the platform provides a) Insured projects, b) Well studied projects and scenarios by the experts from the research centers, c) Supported by the government, d) High number of farms which reduces the lending risk and put the moving average to better values, e) Higher profitability compared to the old traditional agriculture and farming methods, and f) Served by the experts and highly educated engineers.

- FARMS' OWNERS

The small farm operation costs more per acre than the large ones. The cost involves equipment rentals, transportation, etc. Also, due to financial complication, the farm owner may do early harvesting to cash some money losing the opportunity from selling later with higher production. More disparately, the owner may use poor food transportation and packaging. Finally, most of the owners are lacking the skills of marketing and distribution [56]-[57]. Thus, the farms' owners are willing to use the framework for the following reasons: a) They will receive tax break, b) Cost saving in operation, c) Higher income and higher profit, d) Better production and sustainability, e) Marketing and sales efforts are taken care by the system, f) Better food transportation and packaging, g) Better financing to purchase high quality raw materials and supplies, and h) No more early harvesting.

#### D. Ecosystem Transformation

The focus in transformation is to convert the unemployed labor to data collectors from the farm to the decision support system. This way, labor is converted into data material. The labor time is converted into income paid by the farm owners, the vendors' commissions, and the government benefits. The ecosystem betterment achieved by better food production, collaboration, unemployment defeat, food waste reduction

with better handling/packaging, and better environment. Sustainability is achieved by the engagement of the government research centers, institutions, and authorities.

Any ecosystem can be composed from multiple ecosystems. The idea is to compose the countrywide ecosystem from multiple ecosystems that are geographically and demographically distributed. In doing so, and per our proposed methodology, we can insert/convert labor from the unemployed to perform the composition process of the ecosystems. This process will be repeated until all the unemployed labor is absorbed into the global ecosystem countrywide. We will show later how ecosystem conversion process is working by example in an agriculture scenario. A roadmap is places since the national ecosystem transformation is crucial and involves multidisciplinary processes.

#### E. Ecosystem transformation roadmap

The proposed roadmap ecosystem transformation for a national spatial DSS with required data infrastructure to stimulate the economy and reach maximum sustainable development can be semantically like in (Fig 7).

The roadmap contains the following: a) Define/determine the national ecosystem, b) Breakdown the ecosystem, geographically/demographically into smaller ecosystems, c) Determine the existing ecosystem themes and the targeted ecosystem themes, d) Design the transformation process from the existing themes to the targeted themes, e) Determine the required labor for ecosystem transformation, f) Design the cloud-based service for the theme transformation, g) Open the cloud-based services for subscription and registration, h) Subscription will be for the service takers/users, i) Registration will be for the service providers, j) Build analysis tools and theme modeling on the service database/gathered data, k) Build a decision support system (DSS) with analysis tools and theme modeling, l) Build a DSS command and control subsystems as a cloud-based service, m) Consolidate all cloud-based services nationwide using more theme transformation.

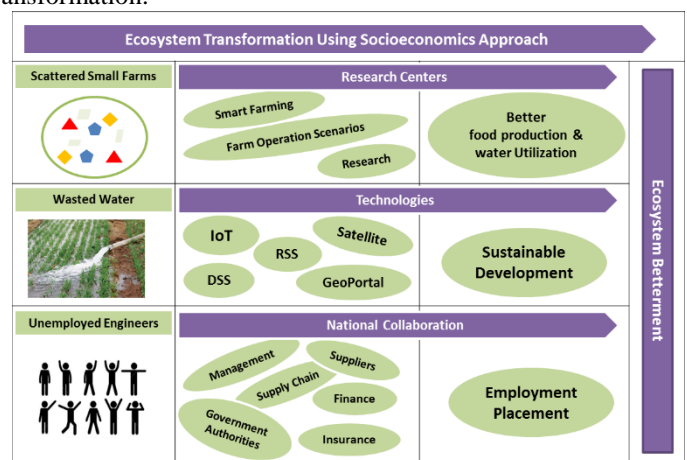


Fig. 7 Ecosystem transformation using socioeconomic approach

*F. The Proposed Ecosystem Transformation Methodology*

We will approve that “Employment can be generated by transforming the ecosystem for betterment”. The method is to blend labor resources, particularly the unemployed, into the ecosystem to convert abiotic elements in the ecosystem to materials required for the economy stimulation where the economic cycle requires labor, materials, and time. Here, we provide a semantic expression to help converting one ecosystem abiotic material to another. But let’s first introduce some definitions and terminologies to the components used in our methodology.

Definition 1: An ecosystem is a community of all components that interact with one another in the same local environment. Ecosystems possess living, biological elements, as well as non-living, chemical and physical components. All ecosystems contain non-living components, which may also be referred to as abiotic components. Air, sunlight, soil, minerals, water and rainfall are examples of non-living parts of an ecosystem.

Example: Junk and garbage recycling. If the garbage is everywhere then use labor to collect it. That will change the ecosystem theme from ugly to beauty and convert from unhealthy to healthy (ecosystem betterment), and garbage collection opens opportunities for employment defeat and making money.

Definition 2: Material here means compound or composite of materials. It’s an endless composing loop which is the nature of the ecosystem anyway. Basically, we can convert a material to another using labor and time or in other word labor can be used to compose a material from other materials and within certain time required for such conversion. Similarly, labor can be used to extract /decompose a material from another material within certain time required for such conversion.

Example: Garbage processing. Garbage is one material which is composed of different materials. Labor can be used to sort garbage into number of materials in groups. Another labor can be used to process a collected group (i.e. plastic materials) and compose it into multiple materials (multiple plastic products).

Definition 3: Tools, devices, machines and similar are considered here as materials since labor is used to compose materials to build a tool/machine or a device.

Definition 4: Matter is material and consequently, time is material, and human resource (labor) is material. Example: It is a matter of time and labor resources to change ecosystem from a state (theme)

to another (theme).

*Method: Ramly’s method is expressed as follows:*

An ecosystem abiotic material can be composed from other materials and/or an ecosystem abiotic material can be decomposed to other materials. The cases in conversion from one material to another are:

If only one element material  $m$  will be blended to target composed material  $M$  using the time of  $n$  labors (of different skills and values  $l_{ti}$ ) in blending/extracting process  $B$  then it can be expressed in the following conversion:

$$M \leftrightarrow B\{(m), (l_{t1}, l_{t2}, \dots, l_{ti}, \dots, l_{tn})\}$$

If only one element material  $m$  will be extracted from composed material  $M$  using the time of  $n$  labors (of different skills/value  $l_{ti}$ ) in blending/extracting process  $B$  then it can be expressed in the following conversion:

$$m \leftrightarrow B\{(M), (l_{t1}, l_{t2}, \dots, l_{ti}, \dots, l_{tn})\}$$

If multiple element materials ( $m_1$  to  $m_x$ ) are blended to one targeted composed material  $M$  using the time of  $n$  labors (of different skills/value  $l_{ti}$ ) in blending/extracting process  $B$  then

can be expressed in the following conversion:

$$M \leftrightarrow B\{(m_1, m_2, \dots, m_i, \dots, m_x), (l_{t1}, l_{t2}, \dots, l_{ti}, \dots, l_{tn})\}$$

If only one element material  $m$  will be extracted from multiple composed materials ( $M_1$  to  $M_x$ ) using the time of  $n$  labors (of different skills/value  $l_{ti}$ ) in blending/extracting process  $B$  then it can be expressed in the following conversion:

$$m \leftrightarrow B\{(M_1, M_2, \dots, M_i, \dots, M_x), (l_{t1}, l_{t2}, \dots, l_{ti}, \dots, l_{tn})\}$$

We can see that the first two cases are special cases of the last two cases. But also the last two cases are similar in which we can say that one formula may be applied for the composing and decomposing. Like: who can say that composing a material from number of elements will cost more than extracting a certain element from number of materials?

In all cases here, labor is used for conversion. Now, we need to put the conversion into an equation that can be mathematically calculated and turned into figures. To equate material with time and labor we should normalize all to a common value like cost for example. So, we equate the value of the material with the value of the time and labor in the currency used (for example Dollars, Pounds...etc.).

The labor and time required to compose/decompose an abiotic material in the ecosystem can be expressed as:

$$\text{Labor in man-hours (LT)} = \sum a_i (L_i T_i)$$

The total labor man-hours (LT) is equal to the sum of the product of  $T_i$  (the time spent by particular labor  $L(i)$  in hours) and normalized value  $a_i$  of a particular labor  $L(i)$ .

And the total value for the labor man-hours is expressed as  $V(LT)$ , where:

$$V(LT) = \sum v_i (L_i T_i)$$

The total value of the labor is  $V(LT)$ , where  $L_i$  is the particular labor ( $i$ ),  $T_i$  is time spent by particular labor  $L(i)$  (in hours), and where  $v_i$  is the value of the hour of a particular labor  $L(i)$  (in currency).

Back to the original assumed conversion process:

$$M \leftrightarrow B\{(m_1, m_2, \dots, m_i, \dots, m_n), (l_1, l_2, \dots, l_i, \dots, l_n)\}$$

We can say that the value of the composed material  $M$  from number of element materials using the time of  $n$  labors (of different skills/value  $l_{ti}$ ) in blending/extracting process  $B$ , it can be expressed in the following conversion:

$$V(M) = V(m_1 + m_2 + \dots + m_i + \dots + m_n) + V(LT)$$

or

$$V(M) = \sum v_m m_i + \sum v_l (L_i T_i)$$

The value of the targeted material  $V(M)$  is equal to the total summation of the values  $v_m$  of the source materials  $m_i$  plus the total summation of value  $v_l$  of labors man-hours multiplied by the time  $T_i$  in hours for each labor  $L_i$  and expressed in the used currency (for example Dollars, Pounds... etc.).

Example: We propose, in a country like Egypt, that we may be able to employ an agriculture engineer to support and maintain 500 acres and integrate them to the national government DSS platform. This means that 20,000 engineers used per million acers. In this scenario we converted the agriculture engineers into data collection and system integrator. From the DSS prospective, the engineers are data sources or information materials. So, the engineer labor work converted to information materials and we were able to quantify it into one per 500 acres. After the conversion, the farms will have better management and support while getting better seeds, fertilizers, and pest control. This leads

to ecosystem betterment and means of ecosystem transformation.

In our agriculture application, the human structure is built from the thousands of labor engineers who are neither part of the government nor part of the existing employed power. So, they are definitely will change the ecosystem themes and they will work in collecting data (material) and be part of the business process. In our theory, a material in the ecosystem can be decomposed to another materials using labor. So, the goal is to collect data materials about agriculture and farming using unemployed labor engineer. Similarly, any material used by/in the ecosystem (farming) is composed from other available materials plus labor where unemployed labor can be inserted.

### V. PROOF OF CONCEPT

An integral part of the presented framework is the communication module that used IoT technology to record and relate the farming information. In this section, we present an open web-based tool for designing and managing BLE networks as a proof of concept of the feasibility of the proposed framework. The presented tool has been the output of a PDP ITAC project developed by Qoudra Company.

Qoudra MANET CAD tool is an open web-based application that facilitates testing and experimentation of real BLE networks. The tool provides easy access to single as well as multiple BLE beacons allowing the user to design, run, and inspect different communication scenarios. The communication scenarios were written using Nodejs scripts that are loaded to and executed by the BLE nodes using the tool interface (Fig. 8).

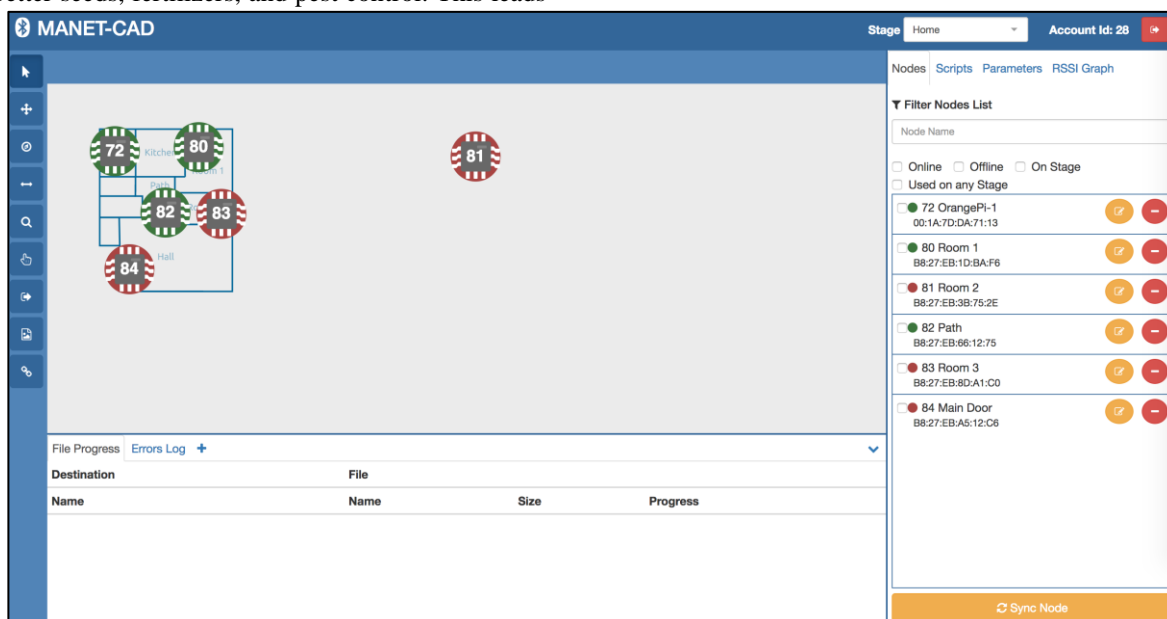


Fig. 8 Graphical user interface of the tool

The Area located at the bottom of the tool's window is a log area and it is used to display several information to the user. There are mainly three types of logging information separated by tabs. These are File Progress logs, Error logs and execution log. The following presents a short explanation for each type of these logs;

1. File Progress logs:

These are the first type of logs that reports the status of the scripts as they get uploaded to the cloud and downloaded to the nodes.

2. Error logs:

These are the second type of logs that report any errors detected by the tool. These could include errors in scripts detected during execution, errors reported by the cloud, or network connection errors.

3. Execution logs:

These are messages sent by the BLE nodes while running scripts to report on their status. The information displayed by these logs differ depending on the role of the BLE node. For advertising nodes, log messages report the time at which the advertising started. For Scanning nodes, log messages report the MAC address for each beacon detected as well as the time at which the beacon is detected. Once the script execution ends, a report is displayed by the tool for each scanner. The report lists the MAC address of all detected beacons, the number of protocol data units (PDUs) received from each beacon and the time that has elapsed before receiving the first PDU for each of the listed beacons.

This tool can be used to test and evaluate the practicality of using BLE networks as the communication module for the proposed framework. The following presents an overview of the BLE technology followed by the preliminary results obtained for experimental BLE inter-communication using this tool. As shown by the experiments the tool detected different BLE behavior that were not considered in contemporary research.

**Overview of BLE Technology**

BLE operates in the Industrial Scientific Medical (ISM) band. The ISM band is divided into forty RF channels, with every two adjacent BLE operates in the Industrial Scientific Medical (ISM) band. The ISM band is divided into forty RF channels, with every two adjacent channels separated by a 2MHz

channel spacing. The BLE channel layout is shown in Figure 9 [58].

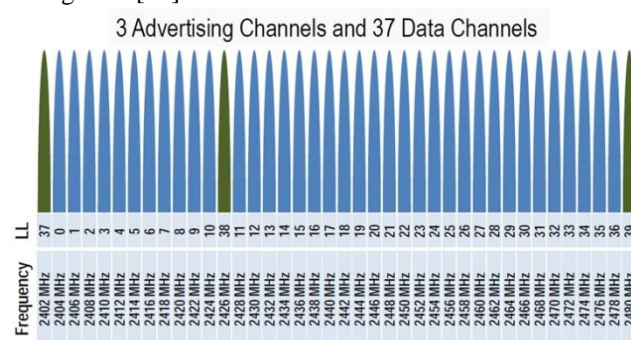


Fig. 9 BLE Physical Channels [58]

BLE channels are divided into two sets; advertising channel set that uses 3 channels and data channel set that use 37 channels. Two multiple access schemes were used depending on the channel set used. When operating on the advertising channel set BLE devices used FDMA, while when operating on the data channel set, BLE device used TDMA. BLE uses Gaussian Frequency Shift Keying (GFSK) to provide 1 Mbps bit rate. To avoid interference with other wireless technologies operating at the same unlicensed 2.4GHz band, BLE used adaptive frequency hopping (AFH). In AHF channels that have interference were marked and unused. According to the BLE Core Specifications [57], BLE devices can operate in two modes depending on the channel set used: a broadcasting mode, or a connecting mode. When operating in the broadcasting mode, BLE devices use the advertising channel set, while BLE devices operating in the connecting mode use the data channels. Each BLE physical channel is subdivided into time units known as events. An event represents the duration within which a BLE device can transmit a Protocol Data Unit (PDU) on the channel.

In the broadcasting mode, a BLE device used advertising events to send data on the advertising channels only, while in the connection mode the communicating devices negotiate the connection parameters over the advertising channels, and once the connection is established data is transferred in both directions on the data channels using connection events.

The operation of the BLE link layer obeys the state machine shown in Figure 10 [59]. Thus, a BLE device can be in only one the following 5 states: 1)

Standby state, 2) Advertising state, 3) Scanning state, 4) Initiating state, and 5) Connection state.

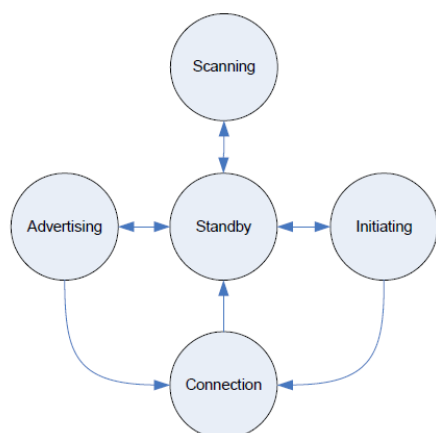


Fig. 10 BLE Link Layer States [59]

Figure 12 [61] below illustrates the operation of the Advertising, Scanning, Initiating and connection processes

All BLE devices start out in the Standby state. In this state, the device was not allowed to send or receive packets. While in Standby state, the device can move to the advertising, scanning, or initiating states. It is also possible to move back to the Standby state from any of the other four states.

The advertising and the scanning states are two complementary states. BLE devices operating in the advertising state are called Advertisers, while BLE devices operating in the scanning state are called Scanners. Advertisers transmit packets on the advertising channels, while Scanners receive advertising packets on advertising channels. The BLE Core Specification defined 4 types of advertising events that an Advertiser can use. These 4 types are: 1) A connectable undirected event, 2) A connectable directed event, 3) A non-connectable undirected event, and 4) A scannable undirected event.

The first two events were used when the Advertiser was willing to establish a connection with a scanner. The last two events were used when the Advertiser and Scanner are both operating in the broadcasting mode with no intention of establishing a connection. On the other hand, there are two sub-states within the Scanning state; passive scanning and active scanning. In passive scanning a Scanner can only listen to advertising packets, while in active scanning a Scanner listens to packets sent out by Advertisers and may request additional information to decide whether to establish a connection to the Advertiser or not. If a Scanner in active scanning state decides to initiate a connection with an Advertiser, it moves first to the standby state, then to the initiating state. Once in the initiating state the device, which is now referred to as an Initiator, can respond to advertising packets to initiate a connection. Once the connection is established, the Initiator acts as the Master of the connection, while the Advertiser acts a Slave. Figure 11 [60] and

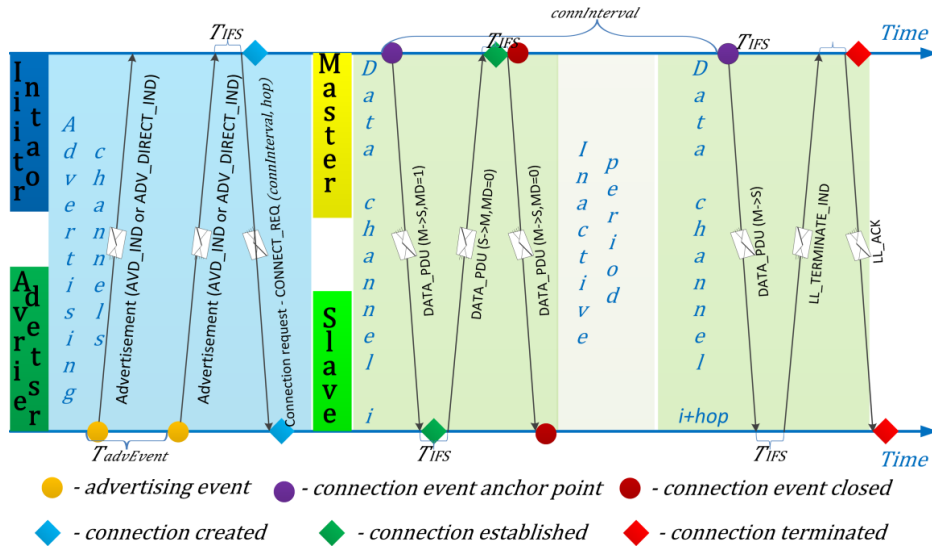


Fig. 11 Illustration of advertising, connection establishing, data transferring, and connection termination in BLE and the related timing [60]

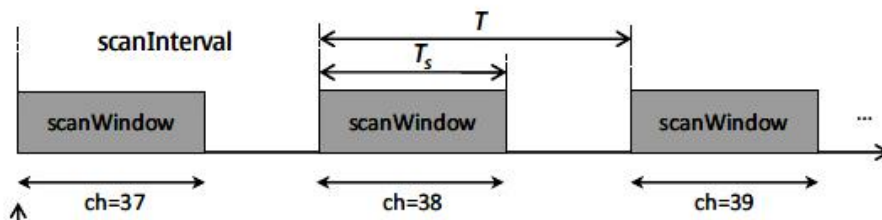
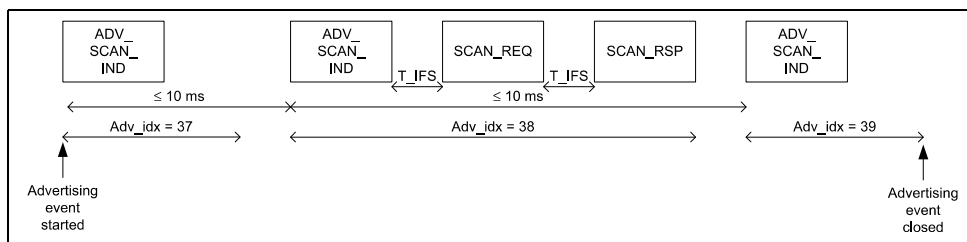
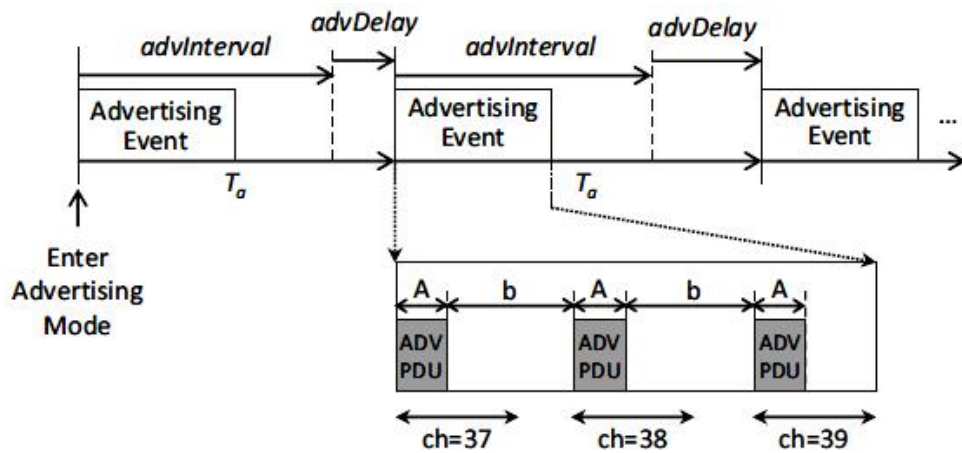


Fig. 12 BLE Operational parameters involved in Advertising and Scanning processes [61]

### **BLE Inter-communication Experiments**

We need to consider scenarios that will be valuable for real life applications. Accordingly, our test cases will mainly consider the effect of the advertising interval, scanning interval and scan window on the latency of discovery.

#### 1) Experiments and Test Cases

Two set of test cases were conducted to investigate the effect of scanning parameters and advertising parameters on the latency of device discovery.

##### 1.1) Evaluating the effect of the Scanning Parameters on discovery latency

The first set of experiments were focused on the scanning parameters; namely the scanning interval (`scanInterval`) and scanning window (`scanWindow`). As defined in the Core Specifications, the `scanWindow` represents the time in which the scanner would listen to the advertising channels, while the `scanInterval` represents the time spacing between the start of two consecutive scan windows. The Core Specification stated that there are no strict timing rules for scanning in general. However, the `scanInterval` should be within 30 msec to 10.24 sec and the `scanWindow` should be smaller or equal to the `scanInterval`. In case that both the `scanInterval` and `scanWindow` are assigned the same value, the scanner will perform continuous scanning. Therefore, our experiments aimed to observe the effect of changing the `scanWindow` with respect to the `scanInterval` on the latency of node discovery.

We conducted several sets of experiments. For each set of experiments, we assigned a new value for the `scanInterval` in the range of 10.24sec to 2000 msec. Within each set, we kept the value of the `scanInterval` constant and changed the size of the `scanWindow`. From the experiment logs, it was clear that there was an upper limit on the maximum size for the `scanInterval` regardless of the value assigned to the `scanInterval` parameter in the scripts. This upper limit was around 3000 sec. We were able to deduce this behavior from the logged timestamp recorded at the scanner for the advertising PDUs. This implied that the results presented by [62] depending solely on the core specifications were not accurate. Accordingly, when operating with physical devices, we need to take into consideration the hardware limitations imposed by the chip maker. We concluded from these test cases that each BLE chip need to be investigated to discover its hardware limitation regarding the values that the scan parameters can assume.

##### 1.2) Evaluating the effect of the Advertising Parameters on discovery latency

We conducted several experiments to evaluate the effect of the Advertising Interval (`advInterval`) has on the latency of discovery. `advInterval` refers to the rate at which an Advertiser will send on advertising PDUs on the advertising channels. The total number of nodes used in all the experiments was nine and the experiments were designed as follows;

- The number of scanners in all the experiments was set at two

- The number of advertisers was initially set at one, and then increased ascendingly to reach seven nodes
- The value of `advInterval` was initialized at the value 100
- For each number of advertisers the experiment was repeated three times, and the latency of discovery for each advertiser was averaged over the 3 trials for both scanners
- The value of the `advInterval` was then doubled and the whole procedure should be repeated again

*Observations:* we were able to deduce some observations

- Despite having the two scanners in very close vicinity, yet the latency of discovery for the same advertiser differs. This can be attributed to the fact that each scanner synchronizes with the advertisers at different time
- Increasing the `advInterval` does not necessarily imply better discovery latency. In fact, increasing the `advInterval` may introduce delays due to the interference and collision of PDUs at the scanners.
- Placing advertisers close to the scanners does not necessarily imply short time for discovery as the number of advertisers increase. This again can be attributed to the interference and collision of PDUs at the vicinity of the scanners

Accordingly, to get a better understanding of the effect of the value of the `advInterval` on the latency of discovery, we plan to perform more experiments using different scenarios and different layouts since the deployment of the nodes need to be taken into consideration as well.

In conclusion, BLE as a communication technology integrates well into the proposed framework. However, further experimentation is required to settle upon the correct layout for the BLE network as well as the correct configuration of the BLE operational parameters.

## VI. RESULTS AND DISCUSSIONS

Through the implementation, we found out during 3 years of design and implementation that:

a) The required software platforms and tools to build the decision support system modules are available in many ways and easy to get particularly the open source platforms and tools. Also customizing the available open source to our needs was not an issue using our local software developers.

b) Dealing with the regulation policies were challenging subject which required a collaboration between the public authorities, scientists and government cabinet to agree on regulations, standards and policies for data sharing, exchanging, hosting, and ownership. Those were achieved by preparing a proposal for the recommended data sharing policies and formulating national committee representing the main

public authorities and the cabinet to discuss, comment on and amend any changes to the proposed standards and policies.

c) Making the data collection technologies available for the project was not an issue since the government has satellite imagery, airborne and other remote sensing facilities and survey technologies available. The challenges were in unifying the metadata required to build the data catalog and automating the upload of such big data. We were able to build the tools to manipulate the metadata so each party can have the chance to adjust their metadata to comply with the system catalog needs. As well, we built the tools to upload large number of imageries to the geoportal which was the repository for all imageries and vector data for previous years.

d) The IoT was used for modeling data collection and monitoring in automatic smart computerized way. However, there is a demand to perform more experiments using different scenarios and different layouts since the deployment of the nodes need to be taken into consideration as well.

e) Designing the correct layout of the BLE beacons to build the communication module of the framework needs further investigation. This is mainly due to the discrepancy that the team discovered in the behavior of the operational parameters between the operation of BLE beacons in reality and that mentioned in the BLE Core Specification. We relate here some preliminary tests presented to the ITAC:

- Evaluating the effect of the Scanning Parameters on discovery latency: The set of experiments conducted to test the effect of changing the scanning parameters on the discovery latency of the BLE beacons revealed that hardware of the BLE chips used do not conform with the Core Specifications. Thus, the research team concluded that when operating with physical devices, the hardware limitations imposed by the chip maker need to be investigated for each chip make, before using the chip in a BLE network.
- Evaluating the effect of the Advertising Parameters on discovery latency: The set of experiments conducted to test the effect of the advertising parameters on discovery latency revealed that (i) for scanners that were placed in the same vicinity, the latency of discovery for the same advertiser differs. This can be attributed to the fact that each scanner synchronizes with the advertisers at different time despite the same setting for the advertising parameters, (ii) Increasing the advertising activity for BLE advertisers did not necessarily imply better discovery latency at the scanner. Similarly, placing advertisers close to the scanners did not necessarily imply short time for discovery as the number of advertisers increase. The last two observations can be attributed to the fact that the layout setting of scanners and advertisers increased the interference and collisions of the BLE packets at the scanners resulting in degrading the network performance.

We concluded that the communication module needs further investigation and testing. Furthermore, for successful implementation of the framework, the

placement of the BLE network need to be tested for each case independently.

f) There is a need to build network of “smart systems for information gathering” (Fig. 13) smart enough to recognize every element required to be measured on the level of each farm, each acre and sub-acre. Also to build a network of “smart systems for pollution monitoring and reporting” that are smart enough to recognize the pollution caused by industrial waste, dead animals, polluted air, garbage, detergents dump, Smearing, impurity, sandstorm, grasshopper, insects, diseases, and pests. These systems should be smart enough to report on the causes. The network of the proposed systems will also manage, stimulate, and develop better agriculture system for better food production and irrigation nationwide.

f) In conventional farming, managing the farm fields needs massive human labor, continuously monitor the soil, regulate the irrigation, and control the fertilizer concentration. As reported by farmers, to maintain the fertilizer level for example, two teams need to work in coordination. The first team will be responsible for measuring the concentration level of the fertilizers, while the second team will be responsible for applying the fertilizers. This is done as follows:

The members of the first team physically visit the fields and manually measure the fertilizer concentration levels for every 50sq.m, then mark the areas that need fertilizer application accordingly.

The members of the second team need to scan the fields for marked areas and apply the fertilizers accordingly.

Finally, the field supervisor needs to physically visit the field to monitor the correct operation and application of fertilizers.

g) When using smart farming, the above scenario can be fully automated using sensors. Sensors can be implanted throughout the field. These sensors sense and report on the fertilizer level in different parts of the field. The supervisor of the field no longer need to physically visit the fields and can easily monitor the whole operation by regularly checking the reports received from the sensors. In addition, the sensors can be used to regulate irrigation such that, in case there is a high raining probability, the farmers can refrain from watering the farm thus avoiding the washing away of fertilizers due to excess watering as well as preserving water.

Thus, using smart farming in farms can improve the crop yield and ease the overall operation. Smart farming uses sensors that measure soil humidity, fertilizer concentration and allows farmers to make better decisions related to both irrigation and fertilizer application. When considering the technology in connecting in the above scenario, BLE sensors can form a mesh network to convey all data gathered to distant gateways installed at the edge of the farm to relay the sensed data to data sinks using cellular communication technologies.

h) We proposed to build a network of skilled human resources that are very close to the farms, farmers, and farms' owners. This network is dealing with the agricultural associations, agriculture experts, and material suppliers (i.e. seeds, fertilizers...etc.). So, basically, we can employ the unemployed human resources (engineers) in helping to advise the farmers for the best food production for their farms. The



network is also used as interface between the farms needs and the other service providers. This way, we assure having accurate information on the farm level while actively working on enhancing the food production.

i) The cost of the network is covered by increasing the food production, reducing the financial burden on the farmer and working for the management companies. Management companies should be involved in consolidating small farms into one managed consolidated land [63]-[64]. Where the company can raise funds for financing, provide the best seed and fertilizing materials, and market and sell the crops for the best prices.

j) We approved our approach using transformation methodology that approved employment can be generated by transforming the ecosystem for betterment.

When all the above services are done, it is expected that the farms value of production will be highly increased, the government will have full information on all crops production. This way, we converted the labor into information material valuable for farms, the farmers, the company and the government.

is straightforward to all the entities via smart services. By doing this the government can easily predict the growth rate of crops in any region. The actual circumstances of the farm are known to the government. Based on the anticipated information, the government can easily design their annual agricultural plan. The government can easily pre-determine the supply and demand of the crops for a particular period and determine their production limit and their financial yield.

The major limitations of the proposed framework are: 1) correct identification of data received and further signal processing that there is a huge data generation when objects are synchronized online, 2) establishment of a robust communication interface, and 3) how to change people's minds.

Collaboration must be the base for the planning of multi-dimension and multidisciplinary activities embracing social, environmental, economic, political, and technical factors. There are two factors to consider in collaboration: the first factor is to bring research centers very close to the real farming operations and provide them with optimal operation scenarios and provide tools to contribute in improving the information system. That was proposed as a cloud-based expert consortium subsystem. The second factor is to add more sources of data by building subsystem as a cloud-based geospatial services for public.

Further work will be directed to validate the performance of the developed framework with real-time data and integrating it with the national decision support system.

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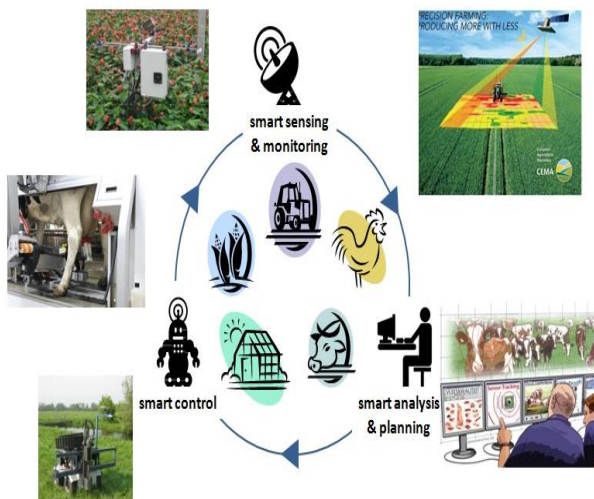


Fig. 13 integrating smart farms into the national DSS after [21]

#### VII. CONCLUSION

Authors successfully developed a data sharing portal (NARSSGeoPortal) to meet the government authorities' needs. We realized that the most challenging was to collect complete and accurate data on time for the decision support system. This data is a big data and requires an army of public participation to collect. We presented how to convert labor (the engineers) into data material valuable for all; the farm, the farmer, the management company, and the government.

Authors developed computer aided design tool that served both researchers and practitioners to attain the full potential of the IoT sensors.

The major advantage of the developed framework is all entities (stakeholders, engineers, farmers, etc.) are connected in an one network which facilitate collecting data and make an analysis for the further changes. Every single information

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