Classification and Trends in Knowledge Research Relevance and context for smart farm technology development

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***Abstract*—With the climate change paradigm, farmers are facing changes in the environment all the time like drought, higher temperature, heavy raining, and the shift of season. Smart farm is a method for helping farmers to plant their crops efficiently. This paper reviews the relevance and context for smart farm development in terms of technology, knowledge for farming, and Life Cycle Management (LCM). The literature shows that several research studies have adopted smart farm technology to monitor and control farm which can help farmers improving their production process and practices. Consequently, the exploit between knowledge for farming and data collected on farm by using smart farm technology is interesting for decision making that can help farmers to manage agricultural production and control the production process more effectively. This research could contribute to identifying the trends and future direction of smart farm technology development.**

Keywords—Smart farm, Lifecycle of plants, Agricultural product

I. INTRODUCTION

Farming is the activity of agricultural product cultivation that is from growing crops or raising livestock to sustain human life. Classification of agricultural product consists of four groups: foods, fuels, fibers and raw materials. The most produced agricultural product is food and more than 20 percent of the global food supply has risen in the past 50 years [1]. Furthermore, the number of the world population will be increased by about 1,500 million people in the next 40 years. According to the prediction made by the Food and Agriculture Organization (FAO), an increase in food demand reiterates on the importance and imperative to increase the awareness on the sufficiency, quantity, and quality of food for the global population [2]. This can be achieved by an attempt to make a proper food distribution to all parts of the world. The quality and quantity of agricultural product is related to management of the life cycle of plants. The life cycle of plants is the sequence of changes and developments of plants which passes from the beginning until the ending of its life [3].

As a result of human activities, the life cycle of plants and agricultural product are suddenly affected from an unpredictable environment situation, such as high temperatures, climate change, heavy rainfalls and extreme droughts [2] which have an impact to the number of crops grown. Therefore, the adoption on the concept of smart farm technology is one of the ways to help reduce the risks from an unpredictable environment.

Smart farm is a concept of adoption smart technologies to collect and analyze data on the overall value chain which farmers can manage and operate their farm in real-time and re-use of data comprising plants, animals and soil to improve the quality of food [2]. Consequently, smart farm is the management of inputs' optimization in a farm according to the veritable needs of crop that are composed of data-based technologies, comprising internet, sensor, global positioning systems (GPS), and remote sensing, for crops' management and reducing the water use, pesticides, and fertilizers. There have been previous efforts in developing smart farm technologies for farming. In this research work, numerous researches and projects on smart farming literature reviews were made by searching on the Scopus online database, Web of Science (WOS) online database and Google scholar. Table I illustrates an example of existing researches and projects on smart farm by a short explanation about their objectives and methods.

TABLE I. RESEARCHES AND PROJECTS ON SMART FARM

Research/Project	Objective	Method
Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis [4]	To reduce carbon emission from farming activity	Change from Conventional tillage (CT) to No-till (NT) and use crop rotation method for sequestrating carbon

Research/Project	Objective	Method
Soil organic carbon changes in the cultivation of energy crops: Implications for GHG balances and soil quality for use in LCA [5]	To reduce carbon emission from farming activity	Using Life Cycle Assessment (LCA) to analyze environment effects of a product which focus on Soil Organic Carbon (SOC) in difference land uses in UK: Oilseed Rape (OSR), Miscanthus, and Short-Rotation Coppice (SRC) willow and forest residues. The biggest impact on soil quality is OSR due to the largest degradation of SOC during the land use.
Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS) [6]	To create framework of farm management	The design and illustration of a component-based framework for agricultural systems (SEAMLESS Integrated Framework) to assess, ex-ante, agricultural and agri-environmental policies and technologies across a range of scales, from field–farm to region and European Union.
Smart Vineyard (European Union project) [7]	To monitor diseases on vineyard	Adopting sensor technology to monitor and detect grape diseases helping farmers to decrease the yield loss, less pesticide, avoids stress, fewer working hour.
Adoption of precision agriculture in vineyard [8]	To improve quality of grapes	Using sensors and remote sensing technology and smart technology into farm to monitor the temperature, soil humidity, humidity, wind speed and direction, and rainfall by sensors nodes via mobile phone which helps farm manager to manage farm efficiently and help to control quality grapes.
Real-time monitoring of GPS-tracking tractor based on ZigBee multi-hop mesh network [9]	To track the tractors into the right route	Adopting Global Positioning System (GPS) technology for tracking tractor in large farm areas via ZigBee wireless network that helps farmers to track their tractors while the machine is running.
A Smart Mobilized Fertilizing Expert System: 1-2-3 Personalized Fertilizer [10]	To suggest fertilizing	Used to suggest the suitable fertilizer to crops via smart phone based on three factors: soil series, rice type and soil nutrient.
Sensor data collection and irrigation control on vegetable crop using smart phone and wireless sensor networks for smart farm [11]	To control irrigation system	Adopting moisture sensor, weather sensor and wireless sensor technology for monitoring and collecting data of humidity and temperature in soil which farmers can monitor and control irrigation system via smart phone.

This paper focuses on the comparison of smart farm technology and life cycle of agricultural products. The paper is structured as follows: Section II describes and reviews the life cycle of agricultural products (plants), Section III illustrates the impact of smart farm to life cycle management of agricultural products, and Section IV provides the discussion and conclusion.

II. Life Cycle of Agricultural Products (plants)

This paper emphasizes on agricultural products obtained from plants as the preliminary study. There are several species of food in the world which is almost 375 thousand varieties of species. Some ordinary terms of plants consist of flowers, trees, brushes and green algae. The life cycle of plants is the sequence of changes and developments of plants which passes through from the beginning until the ending of its life [3]. The basic life cycle of plants is illustrated in Fig.1 [13].

Most plants grow from seeds. To germinate the seeds, they require soil and light depending on the type of seed. After that, the seed will sprout with its first leaves and the seeding will be anchored to the soil by its roots. The photosynthesis is the method of seeding to make its own food using light for processing. Then, young trees grow to mature trees and able to take process in the flowering period. Finally, the mature trees are able to produce productivity. In each steps of planting, the important factors consist of water, light, nutrients and environment for growing which also have an impact on the quality of productivity.

To manage the plants' life cycle, there are different processes depending on the type of plants which has different characteristics. Traditionally, farmers take care of the plants and manage the plants' life cycle by observing the environment themselves and making predictions based on their own experience or observing the neighboring farms.

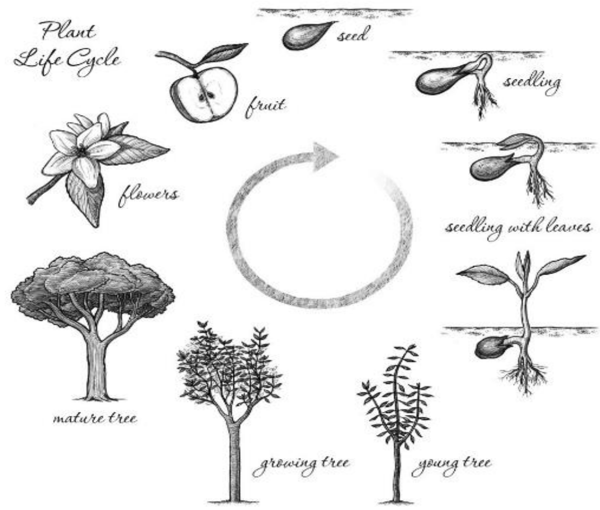

Fig. 1. Basic of Plants' Life Cycle [13]

Due to the current weather conditions, there are unpredictable events such as extreme weather, the shift of seasons, and climate change that always affects to the life cycle of the plants and also resulting in lower quality and yields.

III. Relevance of Smart Farm to Agriculture Products

A. In terms of technology for farming,

Due to the dramatically increase of the world population, the technologies can support farmers to produce more food that follows a higher demand of food. Furthermore, technologies are making the occupation of farming more efficient, less risky, less labor-intensive, and increase sustainability for farming. The types of technology are adopted for farming which help farmers to cultivate plants more efficient, comprised of sensing technologies, hardware and software applications, data analytics, communications system, and positioning technologies [14]. The examples of adoption technology for farming are shown in Table II.

TABLE II. EXAMPLES OF ADOPTION TECHNOLOGY FOR FARMING

Technology	Research/Project
Sensing technologies (sensors and remote sensing)	1. *Smart farm using wireless sensor network for data acquisition and power control distribution:* apply moisture sensors and temperature sensors to monitor soil moisture, air temperature, air humidity and water level for irrigation plants [15]. 2. *Application of Remote Sensing & GIS in Crop Information System – a case study of Paddy monitoring in Jamalpur Block:* apply remote sensing to estimate precise crop area, to provision of crop maps and use data from Landsat TM satellite to extract rice cultivated field [16].
Software applications	1. *FarmLog:* is farm management software providing alert, field information and recommendations helping farmers improve their profitability [17]. 2. CropARM: is a simulation tool that helps farmers to exposure the risk from climate change. The climate record during the 115-year is used for simulation to predict variability year-to-year [18].
Communications system (Wireless network, Internet of Things, etc.)	1. *Integrated Wireless Sensor Network for Smart Sesame Farming in India*: Apply wireless network to monitor farm situation, soil conditions and sesame crops in real-time so that farmers can make a decision immediately. The data will send from sensor nodes on farm to server directly [19]. 2. *Sustainable Farming and the IoT: Cocoa Research Station in Indonesia:* Apply IoT technology to monitor environmental parameters, storing data, managing data collection, and transmitting data to cloud server. Addition, using near field communication (NFC) to collect data from trees equipped [20].
Positioning technologies	1. *Soil color sensor data collection using a GPS-enabled smartphone application:* adopt Global Positioning System (GPS) to locate the field and soil color is detected from color sensors and store to cloud database. Addition, Geographic Information System (GIS) is used to demonstrate a sample point locations and attributes of soil color [21]. 2. *Utilizing a Self-steering Robotic Tractor in the Developmental Phases of Rice-Feasibility Study on Using Quasi-Zenith Satellite System for Precision Farming in Australia:* apply GPS to provide accuracy positioning data with approximately 10-20 centimeters of error for self-steering robotic tractor [22]
Hardware and Software system	1. *Irrigation Monitoring and Control:* setup sensors on farm to detect data and storage on cloud database via wireless or cellular network. This system provides farmers to monitor and control water use on their field via smartphone, tablet or desktop [23]. 2. *Design and Implementation of a GPS Guidance System for Agricultural Tractors Using Augmented Reality Technology:* apply Augmented Reality (AR) technology to allow the tractor driver to see the real plot through eye monitor glasses with the treated zones [24].
Data analytics (Big data, Fuzzy logic, etc.)	1. *Smart farm using wireless sensor network for data acquisition and power control distribution:* use MATLAB-fuzzy logic technology for calculating and controlling irrigation by construct the fuzzy rules. The system can control switch for On or OFF to irrigate automatically [15]. 2. *Flexible and Precise Irrigation Platform to Improve Farm Scale Water Productivity:* apply big data analytics to analyze data that collected from farm for controlling precision irrigation and monitoring water use [25].

Several technologies are adopted on farming such as sensors and sensing technology, wireless network, cellular network, big data analytic, image processing, fuzzy logic, internet of things, etc. [15][16][17][19][20][23][24][25] that helps farmers to cultivate their plants more efficiency. The advantages of adoption technology for farming are reducing costs of production for farmers, increasing quality of production and profitable farm income, improving quality and quantity of productivity, reducing food costs for customer, decreasing the use of resources: water, pesticides and fertilizer, and also providing the benefits of environmental issue.

B. In terms of knowledge for farming

Knowledge is information, facts, skills, and understanding from practice or theoretical which are obtained from education or experience. Knowledge for farming is information and skills in farming production. In general, the basic knowledge for farming practice consists of soil preparation, sowing, manure and fertilizers application, irrigation, weeds protection, harvesting, storage and post-harvesting maintenance as illustrated in table III [26].

TABLE III. BASIC KNOWLEDGE FOR FARMING PRACTICE

Practice	Knowledge
Soil preparation	This is the first step of cropping which is one of important step on farming. The soil is turned and loosens by tilling or doing the ploughing method so that the roots can easily breathe and infiltrate deep into the soil. Addition, earthworms and soil microbes can grow very well in loosen soil which help plants grow efficiently. In the past, the wooden and iron ploughs are used to turn the soil. Currently, the tractor driven cultivator is used to plough the soil which helps to save time and labor.
Sowing	The seeds with good quality are prepared before sowing for getting a high yield. In the past the funnel which has a sharp end was the traditional method for sowing seeds these seeds are filled in the funnel with two or three pipes. The seeds are passed down through the pipes and the end of the pipes penetrates into the soil to make the seeds are placed into soil. Presently, the seed drill is the method that works with tractor for sowing. The seeds are sown uniformly at the proper depths and distances and the seeds are entirely covered with the soil.
Manure and fertilizers application	Due to the waste of nutrients in soil from continuous growing crops, the nutrients are necessarily added to the soil for replenishing the soil. Furthermore, the nutrients are also necessary to grow plants. Farmers need to add the nutrients to the soil for the healthy growth of plants. There are two types of nutrients comprised of manure and fertilizer. The manure is an organic substance that is obtained from the plants or animals decomposition which gives humus to soil. The fertilizer is an inorganic substance that provides concentration nutrient prepared from factories which is necessary for plants: nitrogen, potassium, and phosphorus. The methods to add nutrients consist of spray and sow depending on type of plants and nutrients.
Irrigation	There is a water supply to the plants which has sources from lakes, rivers, canals, dam, wells, and tube wells. In some fields, the traditional irrigation method is used like a chain pump, pulley system, and lever system. On the other hand, the modern irrigation methods like sprinkler and drip system are used in some fields depending on the size of the farm, location, and budget of farmers.
Weeds protection	Weeds are the undesirable plants that scramble nutrients from plants. To control weeds, farmers can use chemicals called herbicide by spraying or removal by cutting them close to the ground or uprooting.
Harvesting	Harvesting is the method of collecting productivity when the productivity is maturation which is harvested by manually or machine.
Storage	The productivity is needed to be stored into a suitable place for each type of productivity to maintain the quality of product. In the storage process, the storage place must be dry, not damp.
Post-harvesting maintenance	After harvesting, the nutrient both organic and inorganic fertilizers are necessary to add to the soil for preserving the soil and add minerals to the soil. Moreover, there is soil preparation and/or plants for planting next time.

C. In terms of Life Cycle Management for farming

The life cycle of the plants is explained in section II which is the general management method of the plants. Due to the climate change issues, there is an affect on the management of life cycle of agricultural product as a result, the Life Cycle Management (LCM) is necessary for making decisions in agricultural production. LCM is a management framework which integrates the concepts and techniques that focus on environmental, technologies, social and economic aspects of services, products and organizations [27].

Life Cycle Assessment (LCA) is one of the analytic tools for considering the environmental impact during the life cycle of agricultural production system [28]. LCA is a crucial component of environmental management that provides a quantitative data related to demands of resource and impacts of environment on the supply chains of food production [29]. LCA consists of four steps that are goal and scope definition, inventory analysis, impact assessment, and interpretation [28]. There are recently two international standards of LCA comprised of ISO 14040 (2006E) which is the environmental management of life cycle assessment on principles and framework and ISO 14044 (2006E) which is the environmental management of life cycle assessment on requirements and guidelines [30]. A calculator tool is the most common application to estimate the environmental footprints which is associated with activities or products. The activity data is entered by end users via a user-friendly interface. The Fieldprint Platform is one example of calculator tools which is created by the Sustainable Agriculture Alliance. This platform is an online assessment framework which empowers farmers, suppliers, retailers and brands use to measure the environment impacts of their crop production [31]. The specific production systems can be modeled by individual farmers and also assess the environmental performance of their management practices improving their performance in production. This platform can demonstrate and document sustainability performance of farmers which use the conceded measurement framework of sustainability. Numerous publications, the LCA framework has been used for analyzing agricultural practices such as apples [32], oil crops [33], apricots [34], cucumber and tomato [35], etc.

D. Gaps analysis from technology domain, knowledge domain and Life cycle of the plants for farming

Good agricultural practices (GAPs) is one of the Quality Assurance System which is the approach of farm level and production level to ensure that human can consume the safety of fresh produce. GAPs is applied to recommend the methods for on-farm section of agricultural product chains and the processes of post-harvesting referred to collection of specific methods applying to agriculture and produce [36]. The summarized of GAPs principle consists of clean soil, clean water, clean hands, and clean surfaces [37]. The GAPs is a framework for agricultural practices which is a conservative way that has a target to create a common practice for farmers. GAPs provides a means for farmers responding to exemplars, existing standards, and certification efforts that offers management options for sustainable agriculture practice, environmental criteria, social and economic [37].

Best Agricultural Practice (BAP) is an innovative way to select the best idea and the most progressive development in societal services, demands of the ecological requirements or economic necessities. BAP is based on the balance among demands of ecological, economical and social desires for enhancing sustainability of production systems [37].

Due to the climate change factor, current farming practices face farm management problems that affect to the quality of agricultural product. Therefore, GAPs has contributed to the development of the farmer's productive process. There are three main domains used to develop the production process: smart farm technology, knowledge for farming and life cycle management domains.

In the technological domain, technology is being applied to help farmers become more productive by including both hardware and software technologies [38]. For example, eFresh is the platform of technology adoption for the safe and sustainable used of production of agricultural product through GAPs. GAPs is used as a framework for the application of technology tools to improve the production process. The eFresh provides timely information and advisory to farmers in crop technology, weather condition updates, prices of commodity, advisory services, support schemes from government, and also link to the market to sale agricultural products to farmers as well [39]. Consequently, technology can help farmers to improve their quality of production, increase productivity, production efficiency, and gain knowledge for farmers, help to grow plants and to care for plants automatically, help for decision making, reduce the costs of production, and reduce labor.

In knowledge for farming domain, knowledge in agriculture is essential for farmers to know how to maintain their output to meet the market demands for both quantity and quality. It enables farmers when they have adequate knowledge of farming practices and the suitability of plants and the environment in the farm such as knowledge of soil types, type of fertilizer, methods to care for crops and produce etc. Knowledge for farming helps farmers to improve production processes, increase quantity of productivity, improve quality of productivity, and also make an appropriate decision when faced with problems on the farm using the knowledge for farming. For example, Smart Good Agricultural Practices is a management information system which is integration of application, Agriculture Strategic, tactical, and operational decision making in the agriculture process. The knowledge from experts is captured. Then, the practices of production process are created for sustainable development [40] [41].

In life cycle management domain, every plant has its own production life cycle, which is another thing that farmers should know because farmers will be able to plan production efficiently. Farmers will be able to cope with the production problems in a timely manner. Consequently, life cycle management helps farmers to improve their production processes. For example, Good Agricultural Practices for Okra, researchers have learned the cycle of Okra production from the beginning to the harvest. The GAPs is then applied by having a storage table for every stage of production such as collecting data of weeds and pests, type and amount of fertilizers and pesticides etc. The concept for the farmers is to be able to check every step of their production and also produce the quality okra for suitable consumption [42].

All these three domains are important for current cultivation. The main thing is helping farmers to improve their production process, quality of productivity from climate change problem, and limitation of resources. The impacts of three domains on farming are demonstrated in Table IV.

TABLE IV. IMPACTION CRITERIA FOR FARMING IN THREE DOMAINS

Impact \ Domain	**Smart Farm Technology**	**Life cycle management**	**Knowledge for farming**
Improve quality of productivity	✓	✓	✓
Increase quantity of productivity	✓		✓
Improve production process	✓	✓	✓
Enhance knowledge for farmers	✓		✓
Automatic system to control and care crops	✓		
Decision making system to cultivate crops more efficiency	✓		✓
Decrease the costs of production	✓		✓
Reduce number of labors	✓		
Increase income of farmers	✓	✓	✓
Sustainability	✓	✓	✓

This table demonstrates the impacts for these three domains for farming that comprise of improving the quality of productivity, increase quantity of productivity, improve production process, enhance knowledge for farmers, automatic system to control and care crops, decision making system to cultivate crops more efficiency, decrease the costs of production, and reducing the number of labors. From the table, smart farm technology can be applied to help farmers in many aspects. For the current planting, farmers have to face with many problems that are not only climate changes or the shift of the seasonal but also the limitation of resources. Consequently, knowledge for farming is not enough for planting crops. Smart farm is necessary to apply with the knowledge for farming that helps farmers in analysis and decision-making on planting the crops at different times in uncertain weather conditions and limitation of resources effectively.

IV. Discussion and Conclusions

A. Discussion

These three domains: smart farm technologies, knowledge for farming and life cycle management have an impact to process of agricultural production. To integrate the three domains, it can improve the production process more effectively. Currently, there are research studies of integration between smart farm and knowledge for farming, and knowledge for farming and life cycle management. However, the integration between smart farm and life cycle management and among these three domains steel to investigate. The integration of these three domains will help farmers in developing sustainable production processes.

B. Conclusions

This paper reviewed the relevance and context for smart farm technology development by searching on Scopus, Sciencedirect, and Google Scholar online database. Due to unpredictable environment like drought, heavy raining, higher temperature, and the shift of season, there is an impact on the farm production process and quality of agricultural products. Knowledge for farming may not be enough for managing the planting practices. Consequently, smart farm is necessary and important which is the adoption of smart technology on farming that is aimed in helping farmers to improve their production and productivity. Several technologies are adopted on farm activities such as sensors and sensing technology, wireless network, cellular network, global positioning system, global information system, big data analytic, cloud database, fuzzy logic, embedded system, machine devices, etc. Farmers can access and manage the production practice immediately by adopting the smart farm methodology on their farm. However, the practice of integrating these three domains, smart farm, knowledge for farming, and life cycle management, is quite complicated but also interesting because farmers can use technology to collect data, access all phases of plants' life cycle, and exploit the knowledge for farming with collected data from the farm for making decisions that can help them to manage their production practices more efficiently when there is a climate change.

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