Smart Agriculture – Demystified

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Abstract. To tackle the adverse effect of climate change, unprecedented population growth, natural calamities, natural resource depletion, and to ensure food security, smart agriculture is the future for agriculture. This extended abstract for this invited talk is focused on some of the important points of smart agriculture to raise conscientiousness among the future research community.

1 Introduction

Throughout history, agriculture has been crucial to human survival, and it continues to be the backbone of the economies of many countries till today. Agriculture's significance has grown alongside the global population and economy. It now encompasses not just farming but also livestock, poultry, forestry, fisheries, food supply chain and so on. Unprecedented population growth, climate change, depletion of natural resources, urbanization, over farming, and deforestation are the crucial factors that are affecting crop yield, disrupting food supply chain, threatening human civilization with food scarcity and high prices.

The food and agricultural industries embrace technological advancements, giving birth to "Agriculture 4.0," a green and smart revolution. Conventional agriculture is transforming into "smart agriculture" and becoming more productive and sustainable by optimizing human labor and natural resources. As a result, crop yield and food production are increasing. Fig. 1 shows the various areas of "smart agriculture." In this article, we have highlighted the key factors of "smart agriculture."

2 Smart Agriculture and Related Terms

Traditional agriculture, which relied on manual labor and produced low yields, is evolving to efficient, sustainable, and eco-friendly "smart agriculture" a.k.a. "smart farming" with the help of technologies like Sensors and Actuators, Internet-of-Things (IoT) [1], Artificial Intelligence (AI) [2], Robotics, and Unmanned Aerial Vehicles. The goal of "smart agriculture" is to maximize both crop quality and output while simultaneously decreasing the amount of efforts required to grow the food [3].

"Smart agriculture" differs from "precision agriculture" in that it doesn't prioritize metric precision. Instead,"smart farming" relies on data collection and analysis enabled by the

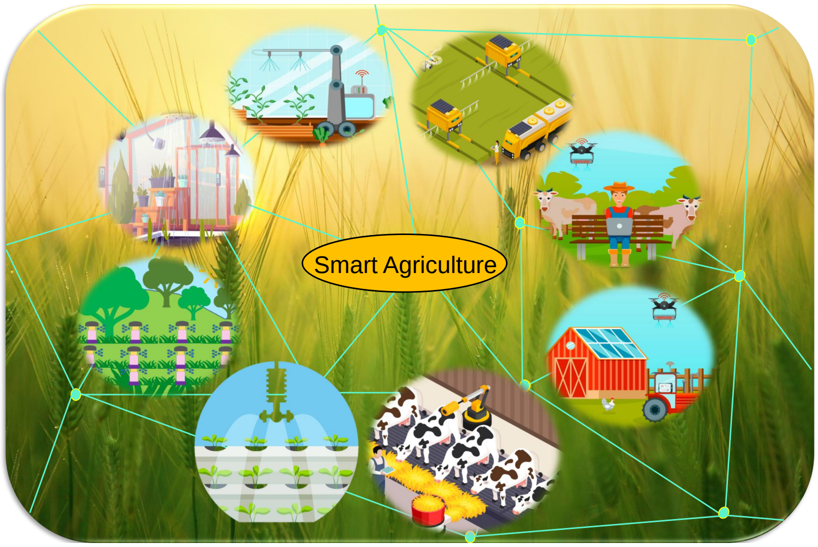

Fig. 1. Smart Agriculture

aforementioned modern computing systems to improve the predictability and efficiency of agricultural processes. Both "smart agriculture" and "precision agriculture" together are the two branches of "digital farming" with different focuses. The evolution of "digital farming" also defines the fourth stage of the agricultural revolution, "Agriculture 4.0".

In this context, a new hybrid system, Cyber-Physical System (CPS), originated from the IoT deployment in physical systems, is gaining popularity. CPSs connect physical things and infrastructure to the internet as well as to each other by integrating sensing, processing, and control networking into these physical objects and infrastructure. The National Science Foundation (NSF) is a pioneer in fostering advancements in the foundational knowledge and technologies necessary to bring cyber-physical systems into existence [4]. Fig. 2 shows the three parts of an A-CPS: physical systems, cyber systems, and network fabric. CPSs enable precision, improve functionality, scalability, resilience, safety, security, and usability over simple embedded systems [5]. "Agriculture Cyber-Physical Systems (ACPSs)" can collect meteorological, soil, and crop data to improve agricultural management. ACPSs may monitor water, humidity, and plant health and employ actuators and infrastructure to control temperature and humidity.

Another important and relevant term is "climate smart agriculture (CSA)" [6]. As climate change has already been started, efforts to overcome the adverse effects of climate change are being included in agriculture for sustainability. Smart agriculture has started to transform to climate smart agriculture to fight against the aftermath of climate change.

3 Climate Smart Agriculture and Food Security

The current ramifications of anthropogenic global warming are presently observable, and their impact on human is irreversible. Furthermore, these consequences are expected to exacerbate in proportion to the continued emission of greenhouse gases into the atmosphere by human activity [8]. By 2100, sea level in U.S. will increase to 6.6ft. Hurricanes will be much powerful and destructive. Heat waves will cover a large area of the earth causing drought and longer

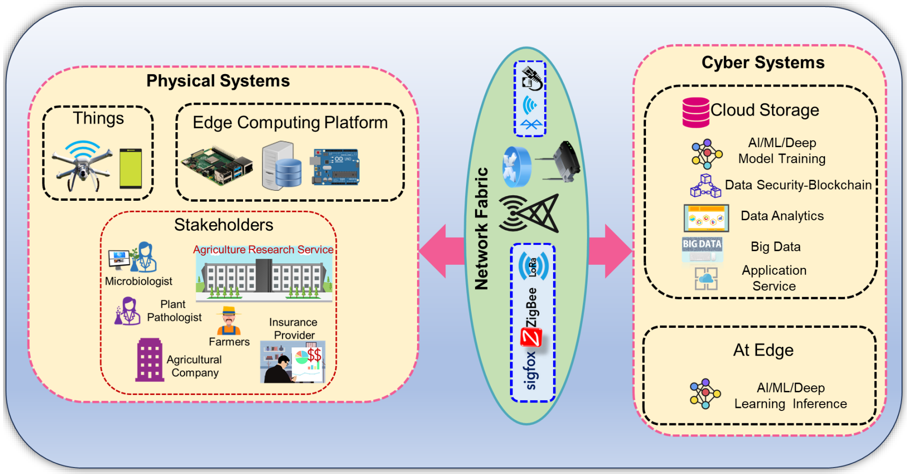

Fig. 2. Elements of a typical Agriculture Cyber Physical System [7]

wildfire session. Precipitation pattern will also change. The deserts may see more rain and fertile land can have no rain. Increase of global temperature will make Arctic ice-free [8].

Climate change impacts crop yield and food production more negatively than positively. Traditional agriculture itself is a major contributor to global warming by emitting 12% of the total greenhouse gases emitted by human activity. Enteric fermentation, manure deposited on pasture, synthetic fertilizer, paddy rice cultivation, and biomass burning are considered to be the agricultural categories with the highest emissions [6].

The CSA emphasizes the significance of collecting actual findings to discern feasible alternatives and essential facilitating actions [6]. It assesses the implications of technology and practices for national development and food security in the context of climate change's site-specific repercussions. It stresses on the sustainable agriculture which increases productivity. It focuses on practices such as less tillage, planting different cultivars and cover crops, efficient fertilizer and treatment use, smart water management, increasing the water retention capability of soil, limiting agricultural waste, precise weather forecasting that can optimize the use of irrigation and fertilizers in farming, and so on.

CSA also focuses on the communication between the policy makers and the producers. As it stresses on the collective effort from all the communities at each level starting from national to individual stakeholders. Advances in Information and Communication Technologies (ICT) and its large scale adaption can build a resilient system. Fig. 3 describes the goals of CSA.

Various efforts are being proposed to limit the causes of climate change, e.g., the AgSTAR program [9] has been introduced to help the agricultural industry cut down on methane emissions from livestock manure. Producers concerned with soil health should reduce soil disturbance while increasing cover crops, biodiversity, and the number of plants with roots in the ground. These practices work together to lessen the impact on the environment by decreasing emissions and increasing carbon sequestration. They also benefit the environment by decreasing soil erosion, decreasing the need for costly inputs like fertilizer, increasing water infiltration, boosting nutrient cycling, and constructing more resilient soils over time [10].

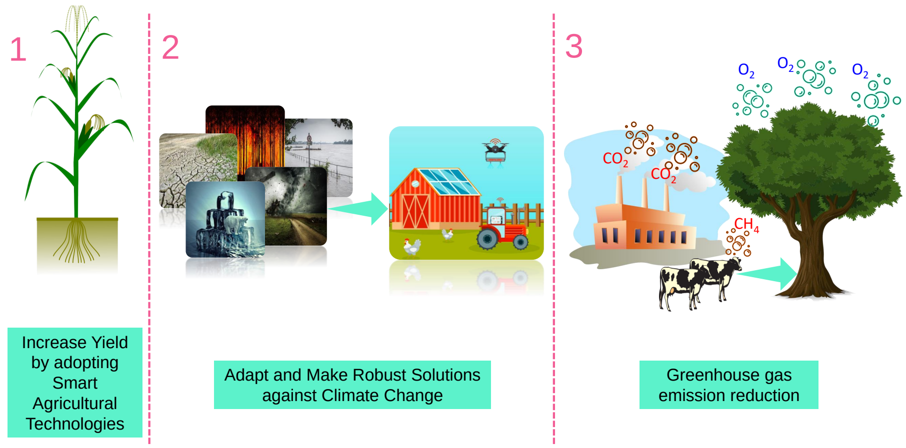

Fig. 3. Goals of Climate Smart Agriculture

4 Smart Agriculture Technologies

All the efforts for sustainable agriculture are possible because of the rapid growth in technology especially in hardware and IC industry, Graphical Processing Units (GPU) and Tensor Processing Units (TPU), computing platforms, and last but not least Information and Communication Technology (ICT). Industries in different sectors are eagerly embracing digital, smart, green, and sustainable ecosystems to meet the challenges of climate change. Because of this, the relation between "man" and "machine" is being rethought. Changes are happening in agricultural sector. "Agriculture 5.0" [11] is knocking at the door.

Artificial Intelligence (AI) / Machine Learning (ML) and IoT are playing the major role here along with UAVs and Robotics as they provide decision making with automation. Remote sensing through satellite monitoring and cloud computing are two established advanced technologies used from data gathering to decision making. Different new concepts like edge computing in agriculture and Software as a Service (SaaS) are emerging. Distributed ledger technology is showing promise and can play an important role i.e., agricultural industry for its ability to store immutable data.

Farms are being equipped with sensors and actuators. These IoT sensors and actuators generate huge amount of data, "big data," which demands for a new stream of data analysis, "big data analysis" in data science.

Farmers now can monitor how far along their crops are in their distinct growth cycles thanks to drone technology. In addition, growers can use UAVs to provide treatments to infected plants. Concept of urban farming like hydroponics, aeroponics, aquaponics, vertical farming, smart greenhouse, livestock monitoring is revolutionizing today's agriculture and ensures sustainable agriculture.

5 Smart Agriculture Challenges

Smart Agriculture has simplified and updated the traditional agricultural industry. However, many problems are still to be solved before widespread technological adoption may occur.

- Smart agriculture uses power-hungry massive machine automation. Farms are large and require many electronic components, therefore power requirements are often considerable. This has hindered extensive agricultural automation. Renewable energy like solar, wind, geothermal, and hydro are being used. However, storage and transmission of such power is always complex.
- One of the most prevalent features of "smart" farming is machine-to-machine (M2M) communication. To accomplish their goal, they utilize a variety of network and communication protocols to exchange information and to coordinate their activities such as ZigBee, Wi-Fi, LoRA, SigFox, and GPRS. However, due to chances of physical damages, farms cannot afford such pricey networks over vast open lands.
- High bandwidth internet connection is not always available in remote rural areas. Unavailability of internet makes the smart agricultural services unavailable.
- Data privacy and security is another bottleneck for smart agriculture. IoT devices generate huge amount of data and moving those data from the user or the origin is not always permissible. So, the solution is moving the service near to the location of data.
- Hardware security is another major aspect of IoT devices. The demand for inexpensive and easy-to-use hardware undermines hardware safety. Because of the prevalence of Hardware Trojans and Side Channel Attacks, the widespread adoption of the IoT network in mission-critical applications is being hampered.
- We don't have any global standard for units and technologies in agriculture. Uniformity will standardize the available services and prices in agro business across the globe.
- Installation of sensors, actuators, or other edge devices, drones, agro robots needs initial capital investment. Investing in those automation is not always easy for small holder farmers who have small margins of revenues.
- As the field size varies from small holder farms to large farms, scalability of solutions is needed. It optimizes all the efforts. Along with scalability, reliability of the solutions will optimize the number of devices. A smaller number of redundant devices which replace faulty devices will minimize the cost.
- To modernize agriculture, one of the biggest challenges is communication gap between the research community and stakeholder farmers. What issues the farmers need to address, not always reach the researchers and the agricultural industry can not fully utilize the benefit of modern technologies.

6 Smart Agriculture Research Problems

As the challenges suggest, there are various areas in agriculture where more research is necessary. For example, research on micro grid structures, power distribution strategies based on requirement and load, supply of electricity without interruption, and energy smart automation can solve the power issues. Affordable and robust communication technologies can provide better communication between devices and systems. More research on data compression techniques, extreme temperature sensors, publicly accessible datasets, data privacy and security aspects, hardware security, robust networking are also necessary to accelerate the progress of smart agriculture. Research on federated learning and edge-computing-based solutions, robust cryptography, and network protocols for tinyML devices are needed to be explored to address data privacy and security issues. Publicly accessible dataset availability is another dire need of AI community for agro research.

7 Conclusions

Today, we live in a world where we cannot deny irreversible climate change. Technological progress and the rapid development of ICT have already boosted the digitization and modernization of agriculture, which results in an increase in agricultural productivity and yields, a decrease in ecological footprints, improved water conservation, increased climate smart efforts, and a decrease in operational costs. Overall, agriculture advances in quality and quantity. However, more climate smart efforts are needed to be practiced. In United States, $19.5 billion has been sanctioned via the Inflation Reduction Act to support climate change alleviation efforts from 2023 to 2027 [12]. Common Agricultural Policy 2023-2027 by European Commission aims to form a sustainable, resilient, and contemporary European agriculture economy. It also has a focus on the efforts for climate change mitigation [13]. In 2011, India has launched *National Innovations in Climate Resilient Agriculture (NICRA)* with $42.7 million to make Indian agriculture—crops, livestock, and fisheries—more resilient to climate change and unpredictability.

Acknowledgment

This article is an analytic synopsis of [3].

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