

*Review Article*

**APPLICATIONS OF SMART TECHNOLOGIES IN SUSTAINABLE AGRICULTURE DEVELOPMENT: A COMPREHENSIVE REVIEW ON PRESENT STATUS AND FUTURE ADVANCEMENTS**

**ABSTRACT**

The pressure on agricultural food production to produce high-quality and sustainable food has increased dramatically as a result of global urbanization, population growth and climate change. Food shortage and population expansion are two of the world's major challenges to long-term sustainable development. So, in recent years technological development such as smart farming has resulted substantial changes in the agricultural production, allowing for 3<sup>rd</sup> green revolution and progression in farming methods. Smart farming (SF) is a method of agricultural production that integrates information and communication technologies to maximise resource efficiency. Smart farming technologies such as automated tractors, artificial agricultural intelligence (AAI), automated irrigation and weather, Internet of Things (IoT), kishan drones and remote sensing can provide realistic solutions to the world's challenges. The accurate application of this technology, in conjunction with the Internet of Things (IoT), is expected to be a beneficial form the farmers to improve their living standards through increased production and profit which is a good indicator for sustainable food security. But due to lack of internet access, high costs and lack of application knowledge there are still barriers to the adaptation and conversion of smart farming. As a result, more research is needed in this area.

**KEYWORDS:** Climate Change, Smart Farming, Sustainable Food Production, Technology

**1. INTRODUCTION**

Globally, the agriculture sector is facing numerous issues like climate change, land degradation and extreme weather events such as heat waves, intense rainfall, cold waves, floods and droughts. Agriculture is particularly vulnerable to climate change because climate change and agriculture are inextricably linked and both occur on a global scale[14]. Climate change causes a range of risks, including temperature, CO<sub>2</sub>, and rainfall, which affect plant growth directly and indirectly through land availability, irrigation, weed growth, pest and disease outbreaks, and so on [14]. During the few past decades, crop yields have been reduced because of climate change and modelling studies indicate that climate change will reduce crop yield potential, particularly in many tropical and midlatitude countries [13]. Adverse influences of global warming include reduced crop quantity and quality due to the reduced growth period following high levels of temperature rise, reduced sugar content, and reduced storage stability in fruits, increase of weeds, blights, and harmful insects in agricultural crops, reduced land [14]. Short-term climatic fluctuations have profound implications on food security so, the Intergovernmental Panel on Climate Change (IPCC) suggests that improving our ability to assess climate-change impacts at national and subnational levels will necessarily require improvements in climate-variable monitoring[32].

**Comment [Ma1]:** \*Kishan or kisan drones?

**Comment [Ma2]:** \*from to for

**Comment [Ma3]:** \*Application knowledge to application of knowledge,

**Comment [Ma4]:** \*of toto

**Comment [Ma5]:** \*Other technologies as GIS and GPS, automatic forecasting, data analytics, smart decision and support system, and SAAS-based agriculture should also be discussed in the abstract the necessity for them and potential benefits.

Farming, on the other hand, has been greatly intensified since the 1560s i.e., after the green revolution, in order to increase the production. Agriculture, horticulture and livestock farming were all organised with the single goal of increasing production [18]. The successes of green revolutions have resulted in a slew of environmental issues, including deforestation, waterlogging, salinity, alkalinity, soil erosion, and the decline and rise of the ground water table linked to brackish water and others [15]. A lot of chemicals, as well as a lot of water and fertilizer, were used which increased the production but at the cost of sustainability. These large-scale monoculture systems may have been beneficial for optimising food production, but they have a negative impact on the environment. But nowadays crop productivity has been limited by declining nutrient-use efficiency, physical and chemical soil degradation, and inefficient water use, while monocultures, mechanisation, and an over-reliance on chemical plant protection have reduced crop, plant, and animal diversity in recent years [36].

**Comment [Ma6]:** \*Found similar to article in <https://www.fme.nl/system/files/publicaties/2022-02/NL%20Magazine%20Smart%20farming.pdf>

For this reason, there is now a greater emphasis on using unconventional technologies (like smart farming) for better farming, decision-making, and policymaking in order to accelerate agricultural growth while maintaining sustainability. Smart farming is a very broad concept which is about the understanding of “what the system needs”, “when it needs this”, “how much it needs” and “where”. Subsequently, actions and input are provided in a precise manner [29]. Smart farming provides (in the future) technologies that allow the cultivation systems to be managed autonomously by machines/robots, transforming the sector into Climate Smart Farming. It converts “large-scale production technology” to “large-scale precise production technology” on an individual level with fewer resources. It also includes incorporating information and communication technologies (ICTs) into farm equipment and sensors for use in crop cultivation and food production systems [31]. Farmers can now use IoT to improve farm efficiency, such as fertilisation, irrigation, harvesting, threshing and climate forecasting, by monitoring with sensors and making better decisions. This development enables farmers to make improved decisions about farm management by making better use of accessible resources, resulting in a higher yield and more income [43]. For these reasons, there is a growing awareness that Smart Farming can play that role, and governments, knowledge institutes, and businesses are increasingly seeking ways to collaborate.

**Comment [Ma7]:** \*Establish the relevance of Figure 1 to the discussion.

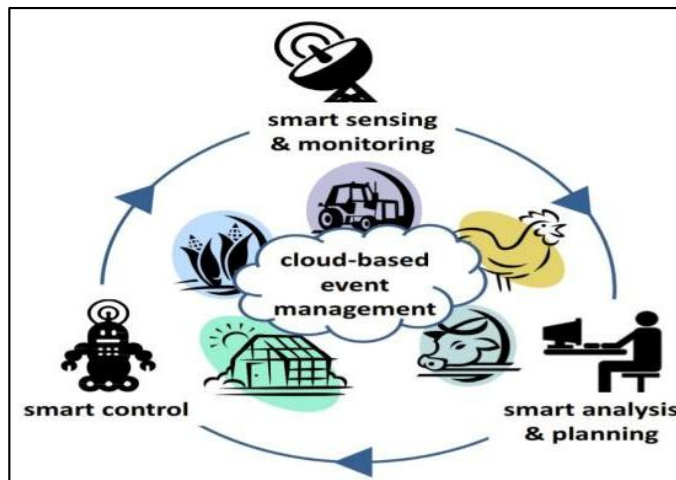


Figure 1: Complete cycle of smart farming (Wolfert et al., 2014).

## 2. NEED FOR SMART FARMING

Agriculture is one of the most labour-intensive and resource using work. Farmers now confront a number of issues which forcing them to make the switch to smart farming.

**Consumer preferences:** The abundance of fast food and other unhealthy meals on the market has resulted in a demand for healthier food products; and quality production is easily achieved through smart farming without any resource degradation.

**Accurate evaluations of resources:** To measure different resource levels, farmers generally conduct manual tests on a regular basis but if they could use smart sensing technology, which is far more accurate, convenient and time efficient [8].

**Advanced spraying:** Advanced spraying by variable rate technology using drone can boost enormous productivity.

**Labour shortage:** Due to rapid urbanization the farming community deal having an acute labour shortage. As a result, modern agriculture should be adopted as smart farming without as labour requirement is less in smart farming.

**Environmental concern:** Farm automation reduces chemical load significantly, improving ecological balance without hampering the production.

## 3. APPLICATIONS OF SMART TECHNOLOGIES

### 3.1. REMOTE SENSING

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft) [43]. Remote sensing has recently been used to improve understanding of the climatic system and its changes. It allows for the monitoring of the ocean, Earth's surface and atmosphere at multiple spatiotemporal scales, allowing for observations of the climate system [45]. By increasing the study of the spatial variability of terrestrial and ocean ecosystems, remote sensing has contributed to the creation of global climate change

**Comment [Ma8]:** \*An opening discussion is suggested for a more thorough explanation and to direct the readers to the substance of each subtopic (e.g. under Need for Smart Farming: Make it in the first paragraph that the arguments that follow are the reasons why smart farming is necessary.)

**Comment [Ma9]:** \*...rapid urbanization, the farming....

**Comment [Ma10]:** \*The statement is confusing. Can be changes as – "As a result, modern agriculture should be adopted using smart farming since the approach has less labour requirement."

**Comment [Ma11]:** \*It is suggested to provide a discussion on how each smart technology works prior discussion of its specific applications. In light of this, Figure 2 shall be discussed under the process on remote sensing then, discussion of its applications shall follow. The same shall be done to other technologies discussed in the paper.

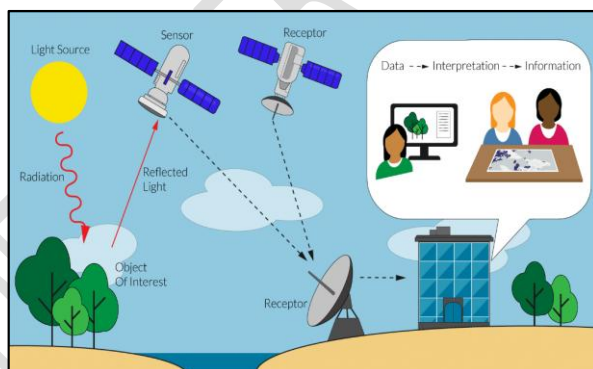
strategies. Furthermore, remote sensing can be used to collect information and data in potentially hazardous (e.g., during fire events) or inaccessible areas (e.g., impervious areas) [29]. According to Yang, J., et al., The following are some instances of climate change-related remote sensing applications [29]. Accurate remote sensing investigates global temperature and trends to improve weather and climate forecasting. It can screen for aerosols (A colloid of fine solids in gas. e.g., Mist, smoke etc. Particle matter is 2.5), water vapour concentration, and changes in precipitation regime as well as examine earth temperature at both the ocean and atmospheric levels. The retreating snow and ice cover is an important indicator of global warming. Which can be measure by remote sensing imagery. Accurate data on sea-level temperature is required to link global temperature changes and their impact on total marine life abundance and coastal modifications and also helps in defining flooding zones, flood hazard maps for vulnerable areas. To decrease and manage the risks associated with climate-related disasters, remote sensing can be used to construct early warning and forecasting systems. It also helps in monitoring water resources and impact due to droughts. Remote sensing combined with spatial analyses helps determine the danger a wildfire as well. It is important for analysing the collected information that can be used to predict climate change patterns, giving room for early warning in case of disaster shifting it from point-based estimation to spatially explicit estimation, with the help of remote sensing guiding decision-making processes on climate change adaptation. It is useful in soil mapping, agro-climate assessment, land suitability, crop condition assessment, and irrigation management.

**Comment [Ma12]:** \*small letter (investigates)

**Comment [Ma13]:** \*Observe subject-verb agreement. Merge the statements into one.

**Comment [Ma14]:** \*Similar text blocks with the article in <https://grindgis.com/remote-sensing/applications-of-remote-sensing-in-climate-change>

**Comment [Ma15]:** \*\*It is suggested to about the particular use of smart technologies in the various domains of agriculture as follows in order to provide a clearer understanding and observe coherence: a. crops, b. livestock, c. fisheries and aquaculture, d. forestry; or as appropriate. This should be done in a way that presents the discussions in a logical and consistent manner. The subsequent technologies covered in the article shall use the manner of presentation.



**Figure 2:** A systematic view of remote sensing

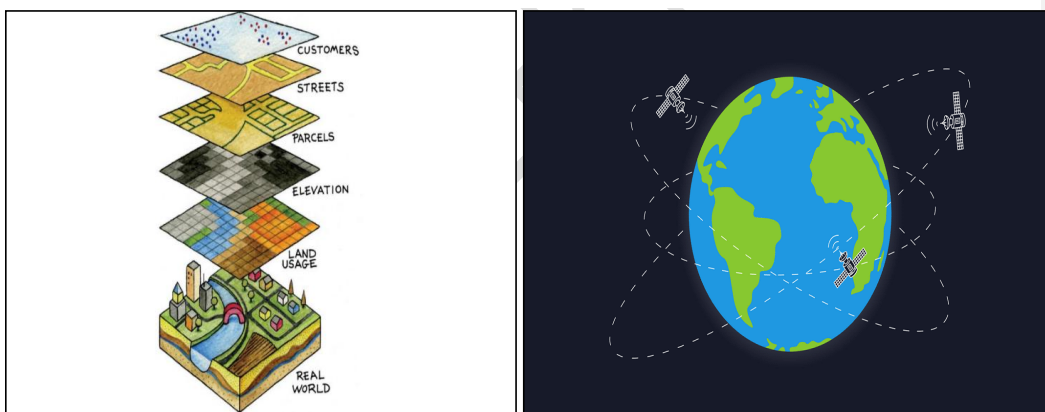
### 3.2. Geographic Information System (GIS) & Global Positioning System (GPS)

GIS is an integrated system of computer hardware and software, along with procedures and a human analyst, that supports the capture, storage, management, manipulation, analysis, modelling, and display of spatially referenced data [4]. In summary, geographical information systems empower users to create maps, integrate information, visualise scenarios, solve complex problems, present powerful ideas, and develop effective solutions in ways never before possible [31]. The Global Positioning System (GPS) provides unrivalled positioning accuracy and flexibility for navigation, surveying, and GIS data capture. With a constellation of 24 satellites, GPS provides continuous three-dimensional positioning around the world 24

hours a day. GPS measurements are three-dimensional so, we can determine both horizontal and vertical displacement at the same time and place [39]. Researchers are using GPS and GPS for climate change information in a variety of ways, including [23]. The water content of the atmosphere, Groundwater hydrology, resource management, environmental monitoring, and emergency response all benefit from the integration of remote sensing (RS), geographic information systems (GIS), and global positioning systems (GPS). It helps in measuring earth quakes. Computer-based GIS and GPS mapping and analysis is useful in geographic planning, identifying environmental changes, where temperatures is abnormally high or irregular in comparison to the global average [29]and implementing action plans. Attempting to visualise a variety of factors that may have an impact on crop growth, industry, and wildlife.

GIS and GPS techniques can aid in the collection and analysis of relevant data, allowing appropriate actions to be taken in advance of climate change occurrences [24]. It creates models to show how a warming climate might affect the ecology of various regions and these techniques can aid in the collection and analysis of relevant data, allowing appropriate actions to be taken in advance of climate change occurrences [24]. Helicopters utilise GPS to track the perimeter of forest fires, making it possible to use firefighting resources more efficiently [41]

Attempting to visualise a variety of factors that may have an impact on crop growth, industry, and wildlife.



**Figure 3:** A brief pictorial depiction of GIS & GPS respectively

### 3.3. KISHAN DRONE

A drone, in technological terms, is an unmanned aircraft. They are more formally known as unmanned aerial vehicles (UAVs) weighing up to 2-20 kg which is remotely controlled or fly autonomously through software-controlled flight plans in their embedded systems, working in conjunction with onboard sensors and GPS [7]. Drones can also help in ways that go beyond monitoring by human. It can accomplish a variety of functions that lead to better agricultural sustainability. Drone operations include irrigation, crop health monitoring,

**Comment [Ma16]:** \* There should only be one statement made in these. Be mindful of the punctuation is used, such as omit the period(.) between "....including. The water content...." and use of capital and small letters for proper and improper noun, respectively.

**Comment [Ma17]:** \*One statement from these. No period on "....implementing action plans. Attempting to...."

**Comment [Ma18]:** \*Label the two illustrations as (a) and (b). Figure 3: A graphic representation of (a) GIS and (b) GPS

**Comment [Ma19]:** \*Clarification: Kishan or Kisan drone.

planting, crop spraying, crop inspection, and soil analysis[30].They can also aid in mitigating the effects of climate change and completing tasks that human is unable to complete due to changing environmental conditions. Drone technology, which was formerly linked with film production or the military, is now being employed in creative ways to tackle man-made climate change [15], which include. Drones can be used to map plastic waste, documenting the level of pollution and giving scientists insight into our litter habits collect data such as weather and soil moisture, allowing for more effective land management and help scientists to track the growth of the problem and are also help in planting trees in Myanmar. These drones can save up to 90% of the water [22]. Farmerscreate Vegetation Index (VI) maps from multispectral camera embedded in drone to disclose crucial crop health information, spot anomalies, and efficiently allocate resources.The drone is outfitted with a weed scanner and crop sprayer, allowing weeds to be scanned from the air and then specifically controlled, resulting in a 30 percent reduction in chemical use[16].High rate of drone planting slows climate change and other environmental damage by sequestering carbon, improving air and water quality, and preventing erosion[17].Bees have been dying off in huge numbers due in part to climate change. Japan's National Institute of Advanced Industrial Science and Technology used a 1.5-inch drone to pollinate Japanese lilies [19]Usingdrones to deliver packages instead of trucks could help reduce emissions associated with package delivery[17].Now Scientists can simulate shoreline changes to account for increasing sea levels, run storm impact models, and anticipate which places will be most at danger of flooding using a drone-enabled LiDAR sensor with the drone aid

**Comment [Ma20]:** \*The statement is incomplete as the phrase "which include.." suggests other idea/s will be presented.

**Comment [Ma21]:** \*Please also observe putting space after period and the first letter of the next sentence. Similar occurrences were observed in the paper.  
\*Please correct spacing error as indicated by blue wavy underline.

**Comment [Ma22]:** \*...drone aid.



**Figure 4:** The awesome benefits of drone technology

**Comment [Ma23]:** \*May be written as Figure 4: The benefits of drone technology

### 3.4.AUTAMATED TRACTOR OR DRIVERLESS TRACTOR

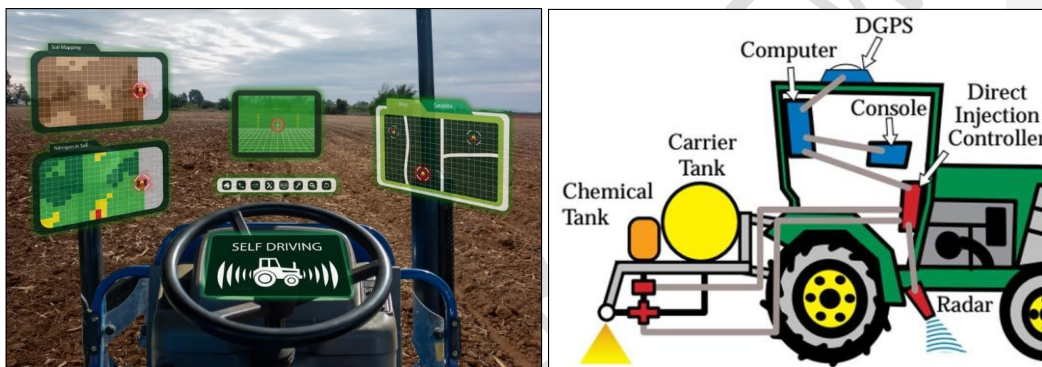
A driverless tractor is an autonomous farm vehicle that provides high tractive effort (or torque) at low speeds for tillage and other agricultural tasks[11]. Remote control is available for these tractors. With the advancement of technologies such as vision systems, light detection tools, GPS, and so on, smart tractors will become increasingly self-sufficient in agricultural use. It has an Auto-steer technology that is based on GPS and assists the tractor in travelling in a straight line[44].The driverless tractors will do the planting automatically

and with high accuracy, resulting in seed conservation and this could aid in the alleviation of farm labour shortages and this tractor can work with high efficiency thus reduce the diesel

need hence reduce the CO<sub>2</sub> level indirectly. The tractors' sensors will be able to collect data

on soil conditions, crop maintenance for already planted crops, and harvest data before and after cultivation. With variable rate technology embedded in tractor reduce the chemical load

in environment as well as farmers will also be protected from health risks associated with chemical spraying



**Figure 5:** Automated Steering System of Tractor and variable rate technology embedded in tractor

**Comment [Ma24]:** \*Observe proper line spacing.

\*The driverless tractors will do the planting automatically and with high accuracy, resulting in seed conservation and this could aid in the alleviation of farm labour shortages and this tractor can work with high efficiency thus reduce the diesel need hence reduce the CO<sub>2</sub> level indirectly. Can be stated as:

With their high level of accuracy and autonomous planting, driverless tractors can help conserve seeds and alleviate the labor constraint on farms. Additionally, because of their great efficiency, they require less diesel, which indirectly lowers CO<sub>2</sub> levels.

\* The technology is operational and currently in use. It is important to state that the tractor is capable of carrying out the specified applications being discussed, such as in the statement below. This also observes coherence in the discussion.

The tractors' sensors collect data on soil conditions, crop maintenance for already planted crops, and harvest data before and after cultivation.

\*With variable rate technology embedded in the tractor, the chemical load in environment is reduced, and the farmers are protected from health risks associated with chemical spraying as well.

**Comment [Ma25]:** \*Suggestion: Figure 5: The tractor's automated steering system and embedded variable rate technology

### 3.5.IOT-BASED AGRICULTURAL SENSOR

IoT is defined as the connection of network, hardware devices, software, and most importantly human beings exchanging data for specific purposes. According to the researchers, the ability of computers within a network to make decisions without human intervention has evolved over time with the help of IoT [25]. IoT has the potential to play a critical role in combating climate change by assisting us in reducing greenhouse gas

**Comment [Ma26]:** \*Internet of Things (IoT)

emissions and living more sustainably. The smart systems improve the accuracy and efficiency of devices that monitor plant growth and even livestock raising. Wireless sensor networks (WSNs) collect data from various sensing devices [30]. Sensors used to monitor environmental conditions such as soil nutrients, air temperature, and humidity, defining the best time and location for planting, irrigation, fertiliser application, and so on, resulting in more efficient use of agricultural land and resources, improved output, and higher quality production[51]. Chand et al. (2021) succeeded in designing a multi-purpose smart farm robot (MpSFR) that can carry out water sprinkling and pesticide spraying based on IoT and computer vision (CV) technology [30]. Automated sensor in Automated weather observing system (AWOS) measure meteorological operations, monitor of climatic conditions by weather stations, combining various smart farming sensors weather forecasting with 80-90% accuracy[6].

According to the report of the Food and Agriculture Organization (FAO 2017), about 20–40% of crops are lost annually due to pests and diseases and as a result of lack of good monitoring of the state of the crop[30]. Carbon savings are also possible in the developing countries. Low-cost, low-power IoT devices could deliver precision agriculture (which reduces fertiliser, pesticide, and water consumption) to developing countries much faster. Hence, the use of sensors and smart systems allows monitoring of weather factors, fertility status, and also determining the exact number of chemicals necessary for crop growth [30]. IoT-powered sensors can obtain accurate real-time information on greenhouse conditions and this IoT-smart services and industry could account for a 3 percent carbon reduction by increasing efficiency [26]. With IoT sensors, farmers can collect a plethora of metrics on every aspect of the field microclimate and ecosystem, including lighting, temperature, soil condition, humidity, CO<sub>2</sub> levels, and pest infections[8]. The rain drops sensor and soilmoisture sensor send SMS notifications to the farmer about the moisture content of the soil. Sensor-mounted devices used by individuals to monitor and warn about air quality levels and can detect the level of sustainability, CO<sub>2</sub>, CH<sub>4</sub> measurement is critical. Sensors is a highly sensitive, near-infrared sensor for accurate and reliable measurement of CO, CO<sub>2</sub>, CH<sub>4</sub> gas. Drone authorities have been successful in conserving some rare species by installing motion-sensing cameras throughout forests. Another important sensor for monitoring the tree in the continuous basis is tree talker (TT). This device is very useful for collecting data from the trees of agroforestry system and urban areas. It includes variety of sensors along with microcontrollers. It collects the data of several plant parameters like: water transport in the xylem of the trunk (sap flow), wood temperature and humidity, multispectral signature of light transmitted through the canopy, tree trunk radial growth, accelerations along a 3D coordinate system used to detect tree movements, air temperature and relative humidity which can be additionally complemented by soil temperature and volumetric water content (SWC)[49].

**Comment [Ma27]:** \*...technology [30].  
Automated sensore....



**Figure 6:** IoT based sensor used in field

UNDER PEER REVIEW



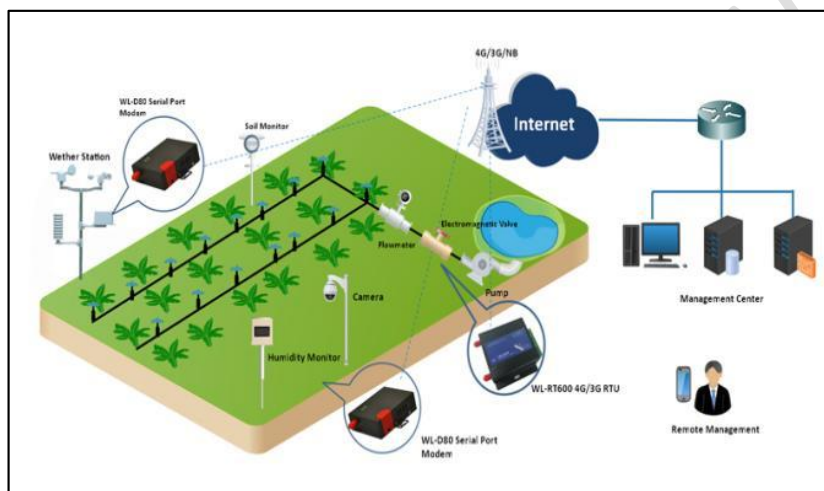
**Figure 7:** Tree talker sensor

### 3.6.AUTOMATIC WATERING AND IRRIGATION

An automated irrigation system is one that operates with no or very little manual intervention aside from surveillance[26]. Almost any system (drip, sprinkler, surface) can be automated using timers, sensors, computers, or mechanical devices[26]. It makes the irrigation process more efficient, which can result in savings for the end user, not only in monetary terms, but also in natural resources such as water and energy, resulting in a more sustainable environment[7]. Using Wireless Sensor Networks (WSN) directly in the field to collect real-time data on the current state of the garden and cross-referencing this information with weather forecast, evapotranspiration, and garden specifications, our proposed solution is able, using artificial intelligence algorithms, to predict/calculate the real water needs for that specific garden and adjust the irrigation controller without human intervention [21]. The smart irrigation system is entirely powered by the solar panel's photovoltaic (PV) cells. The generated power is stored in a battery pack and used to power the pumps at the water management and control station. The solar panels charge the battery during the day so that when there is no solar irradiance, the battery pack has enough power to keep the pumps running when needed [1]. Advantages of automatic watering and irrigation system. A rain sensor detects rainfall and prevents the irrigation system from operating during a rain event[18]. With this solution, it is possible to save up to 34% of water when using sensor data from temperature, humidity and soil moisture, or up to 26% when using only temperature inputs [21].Soil moisture sensors measure the water content of the soil and are a management tool that can help determine when irrigation is required[18].The sensors are placed at the crop rooting depth (typically, 15–30 cm). Moisture sensor triggers irrigation when 20% of

**Comment [Ma28]:** \*This is to make clear whether the term in the statement is necessary since it implies that the paper is making a proposal that warrants action.

available soil water is depleted [21]. Irrigation process starts and stops exactly when it needed thus reducing energy consumption, using water from numerous sources and increasing water and fertiliser efficiency. Furthermore, surface drip irrigation can be linked with fertigation (irrigation water plus fertiliser), which not only increases irrigation efficiency (20–305%) but also decreases fertiliser losses (20–40%) and increases crop yield (10–20%) depending on soil, crop, and environmental conditions [35]. This improved technology has the potential to increase water application efficiency and use water judiciously based on crop stage and requirement.



**Figure 8:** Sensor based automatic irrigation system

### 3.7. AUTOMATED WEATHER FORECASTING

An automated weather station is an automated version of a traditional weather station. They can be single-site or part of a weather network [5]. Humans are heavily reliant on the weather; it plays a role in every aspect of our lives, from feeding us to providing power for our ever-increasing needs. Climate change has warmed the planet and altered our weather patterns, making extreme weather events like droughts and floods more likely [9]. High-tech weather forecasting technology can aid in the fight against climate change by monitoring meteorological conditions to aid decision making, whether in the aviation or shipping industries, or by assisting us in understanding and forecasting natural hazards and disasters, allowing us to reduce the risk of adverse events – and the costs, environmental, economic, and social [2]. At the farm level, an Automatic Weather Station (AWS) is used to provide real-time weather information. The AWS also provides information on soil moisture and temperature, which helps to determine how much water is needed. Without a doubt, AWS is a valuable tool in the hands of farmers today. The main benefits of using a weather station in agriculture. AWS outperform traditional ones because they produce more precise and frequent

measurements, require less power, and can function almost anywhere and help farmers, scientist to take action quickly without any data leakage and quality deterioration. Another accurate measurement of current weather conditions for specific location and surroundings. The ability to view historical data and perform long-term statistical analyses and graphs of data going back up to ten years, including calculations of minimum and maximum values, No additional costs or fees associated with operating the station

**Comment [Ma29]:** \*May take into consideration changing the sentence to better convey the author's specific ideas.



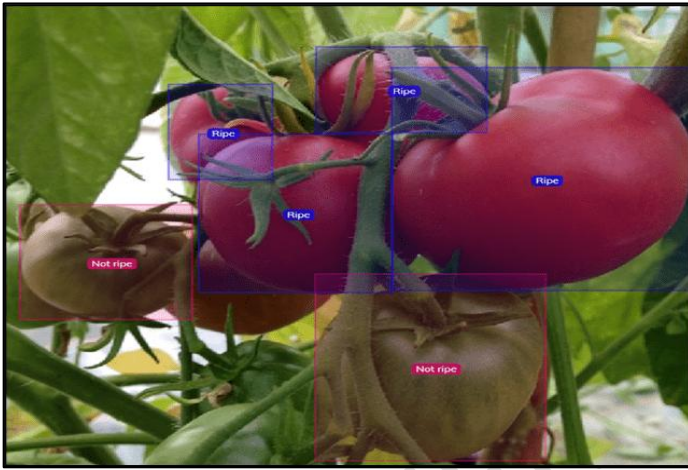
**Figure 9:** Automated weather observing system

### 3.8. USE OF ARTIFICIAL INTELLIGENCE & DATA ANALYTICS

Artificial intelligence (AI) is steadily emerging as a technological evolution in the agriculture industry. AI-powered solutions will not only help farmers improve efficiencies, but they will also increase crop quantity and quality while also ensuring a faster time to market[33]. AI systems are assisting in the improvement of overall harvest quality and accuracy – a process known as precision agriculture[28]. These robots are capable of eliminating 80 percent of the volume of chemicals normally sprayed on crops and reducing herbicide expenditure by 90 percent [40]. This method builds models that can "keep an eye" on plant health by using classification, detection, and image segmentation methods[33]. AI technology helps in detection of plant diseases and pests by using image recognition technology based on deep learning can analyse and Interpretate the images faster than humans, allowing it to assess crop health, anticipate yield, and detect crop malnutrition. AI sensors can detect and target weeds and then decide which herbicide to apply within the region[33] and it can improve agriculture efficiency, as they reduced operating costs and reduced operating time. In addition, the robots can reduce the environmental pollution of up to 80% of farm's pesticides [27]. These intelligent AI sprayers can drastically reduce the number of chemicals used in the fields, improving the quality of agricultural produce while also reducing costs[40]The smartphone collects the image, which is compared to a server image, and then provides a diagnosis of that specific disease, which is then applied to the crop using an intelligent spraying technique [12]Scientists used A.I analytics tool to determine the best time to sow the

**Comment [Ma30]:** \*Consider discussing the Artificial Intelligence mechanism works.

seeds for maximum yield and the ripening time of a particular tree. They can also advise farmers and governments on future price patterns, demand levels, crop type to sow for maximum benefit, pesticide usage, and so on [33]. To summarize, AI alleviates the scarcity of resources and labour to a large extent, and it will be a powerful tool that can assist organizations in dealing with the growing complexity of modern agriculture [12]. AI models can alert farmers to specific problem areas, allowing them to take immediate action.



**Figure 10:** AI technology helps in detecting ripening status in plants

### 3.9. SMART DECISION SUPPORT SYSTEMS (SDSS)

Smart Decision Support Systems (SDSS) are being introduced in the agricultural industry to help farmers and anybody else interested in agricultural investment make educated decisions [3]. There are numerous decision support systems in agricultural management, such as irrigation management, fertilisation, and others for service operations. Furthermore, Giusti and Marsili-Libelli (2015) proposed a fuzzy decision support system for irrigation management, as the system includes spatial location data and crop characteristics such as crop growth stages, planting date and water requirements, precipitation, temperature, as well as soil characteristics and water requirements [20]. It also contains an interpretation system that regulates irrigation timing to maintain soil moisture within the suitable limits; this system increases water use efficiency (WUE) and quality of crop yield.



Figure 11: Graphical user interfaces (GUI) for agricultural DSS.

### 3.10. SAAS-BASED CLOUD SOFTWARE



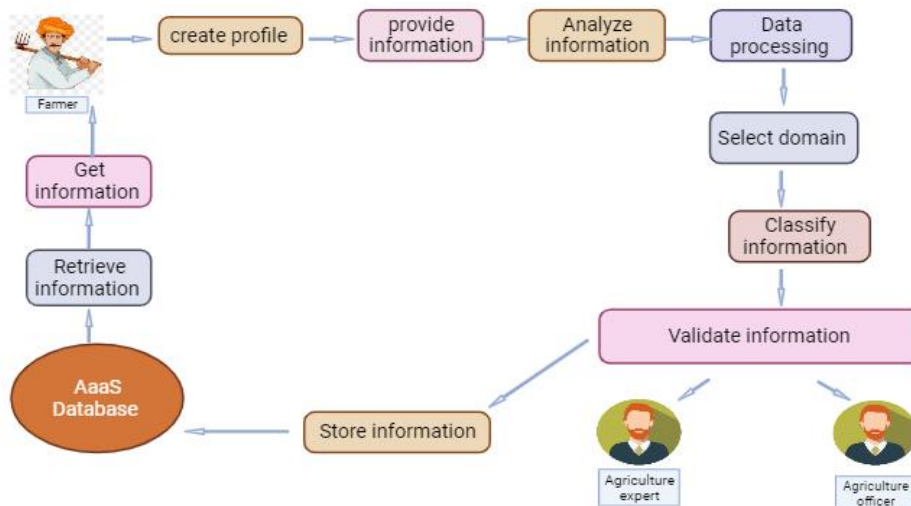
Figure 12: Benefit of SAAS-based cloud software

Farmers will be pushed to make data-driven decisions since global food consumption is predicted to rise significantly in the near future. Changing weather patterns, increasing pest infestations, and unproductive soils, on the other hand, all have an impact on data collection methods and, ultimately, agricultural outcomes. This has increased the demand for SAAS-

based agriculture that can provide precise data to assist farmers in effectively dealing with these changes [37]. Cloud computing can help farmers make better farming decisions by collecting data from sensors, weather stations, and satellite photographs. Farmers, for example, can use a SAAS platform and powerful AI/machine learning algorithms to evaluate a combination of satellite data and ground truth data for better decision making and farming practises. In addition to data collection, cloud computing can assist farmers in better understanding their farm environment. Cloud computing in farming can give agribusinesses with actionable insights that can aid them in making key financial and strategic choices. It enables effective farm management through digitization by providing total view of people, processes, and performance across the field. As a result, SaaS solutions can aid in precisely mapping and monitoring farm conditions in order to ensure effective agricultural activities with data-driven decision making[10].

**Comment [Ma32]:** \*Observe consistency in the use of acronyms – SAAS or SaaS.

**3.10.1.** Among different cloud-based software system one of the most user-friendly autonomic information systems is Agriculture-as-a-Service (AaaS). AaaS has the ability to manage all types of agricultural data based on different based on different domains. It provides mainly 3 types of services like – i) Software as a service (SaaS), ii) Platform as a Service (PaaS), and iii) Infrastructure as a Service (IaaS). SaaS is the interface where the user interacts with software. PaaS work as interlink between cloud subsystem and user subsystem. IaaS is a resource manager which automatically manages the data based on the particular request[46].



**Figure 13:** Functional aspects of AaaS

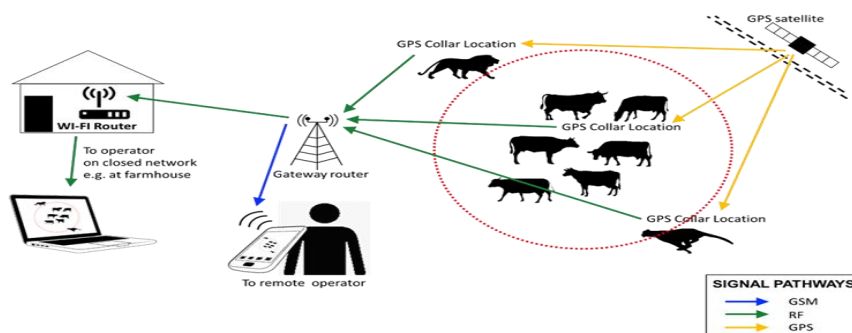
**3.11. Cloud based system for livestock monitoring**

Now a days application of smart farming technology became very popular in the livestock farming also. PLF precise livestock farming indicates the advanced management of farm animals using IT and IoT and Wireless Sensor Network (WSN) technologies [47]. Livestock monitoring can be done mainly in three ways First, monitoring the individual animal for analysing their health status and this reduces the chances of collective infections caused by illness. Second, tracking the animal location during the time of grazing. Third, maintaining the optimum environmental condition for the animal by monitoring the farm environment. From Vaughan's research, the body weight of animals on a livestock farm is measured by using different IOT application. A sensor is installed on the farm floor which measure the weight and the gait data of the livestock. The cloud-based system has three components [48]. First, network layer where, data are collected from the node is send to cloud platform. Each animal wearing a sensor containing neckless considered as nod. Second, is the cloud platform where the manipulation of collected data happens. Third, component is user interface. Here the information about the nod, there location stratus is displayed on the screen [47].

**Comment [Ma33]:** \*Write "now a days" as "nowadays" as the accepted way of writing the word.

**Comment [Ma34]:** \*Kindly spell out PLF as first used in the paper.

**Comment [Ma35]:** \*May consider rephrasing the statement. Suggested: Here, the information about the nod and its location stratus is displayed on the screen



**Figure 14.** Remote livestock management

#### 4. THE BENEFITS OF SMART FARMING

Benefits of smart farming include:

**Increased Efficiency:** Farmers can increase their efficiency through smart farming. Farmers can now produce more products in a shorter period of time. They are quickly inspected, anticipate.

**Higher crop quality:** IoT monitoring systems aid in the maintenance of optimal conditions, resulting in higher crop quality. Weather monitoring in agriculture, for example, aids in estimating the precise supply of water, chemicals, and nutrients required to produce high-quality crop yields. Farming products grown with IoT monitoring systems can also meet market specifications better than other products[34]

**Less reliance on pesticides:** Pesticides are not only toxic, but their use also incurs costs. Smart pest monitoring systems reduce the need for pesticides, the costs associated with them, and the hazardous effects of chemicals on the environment and human health[34]

**Higher sales price and lower costs:** Obviously, greener, healthier products grown with cutting-edge Agri-technologies will have higher sales prices and, as a result, bring in

**Comment [Ma36]:** \*"They are quickly inspected, anticipate." Consider elaborating to refer that smart farming technologies help farmers to quickly inspect the condition of the crop and anticipate concerns for immediate decision-making.

more revenue. Smart farming leaders will reduce crop labour, water, and nutrient costs[18]

**Labour shortage is easing:** Labour in some farming branches can account for up to 50% of total costs. This situation is exacerbated by a labour shortage. The use of robots for seeding, harvesting, watering, and monitoring reduces the need for employees to perform a variety of monotonous tasks.

**Comment [Ma37]:** \*reduces, one word

**Eco-friendly Agriculture:** The use of pesticides scares many people, which is why agriculture is gaining a bad reputation. Robots are changing the game to be more environmentally friendly: they can add pesticides with great precision, which is nearly impossible for a human to do.

**Save time and be more organised:** Remote monitoring of water levels and weather conditions saves time that would otherwise be spent physically going out to the fields. Furthermore, knowing weather trends allows you to better plan your day's activities while avoiding rain or other bad weather.

**More efficient crop monitoring with less human error:** automated crop monitoring will result in more accurate data in less time and with less labour

**Comment [Ma38]:** \*start with capital letter, for consistency of discussion/presentation under this topic.

## 5. ECONOMIC OPPORTUNITIES IN SMART FARMING

Smart farming is important in addressing social challenges and moving toward more sustainable food systems and nutritious foods while also providing farmers with economic opportunities. Accurate measurement and appropriate plant growth factor adjustment result in higher product quality and productivity is higher than conventional cultivation due to cost savings from resource use (water and fertilization) and a higher price. Increasing the product weight per unit and reducing the amount of labour increases the return per unit area.

## 6. ROLE OF SMART TECHNOLOGIES IN SUSTAINABILITY

Sustainable development is becoming increasingly important in the agriculture sector because the current underutilization of resources and energy, as well as the pollution caused by toxic chemicals, cannot be sustained at current rates. Agriculture can be more sustainable by using fewer (or no) toxic chemicals, conserving natural resources, and lowering greenhouse gas emissions. Technology applications could assist farmers in making better decisions based on accurate data, resulting in low-input agriculture[38]. Agriculture can be made more sustainable by making better use of data in decision making. Indeed, innovative farming is regarded as a subset of data analysis and mathematics. Farmers are subjected to a variety of variables on a daily basis, ranging from soil diversity to climate change[32]. Such variations necessitate careful examination in order to implement the best farming practices. Smart farming, which highlights the use of big data in decision making, can help with some of these challenges as well as fulfilling any production targets. Unlike in the past, farmers can now collect data and make informed decisions using smart farming approaches. Farmers can use a variety of data analysis techniques. Farmers, for example, can determine the fertility of their farmland using smart technology by analyzing and comparing satellite images, and then using the data to determine the yield potential of a given land. Farmers who use smart farming find

it simple to measure variables and process data with precision. This is done to make tasks easier, increase yields, cut costs, and move toward more sustainable agriculture[38].

## 7. CONCLUSION

The Food and Agricultural Organization of United Nations (FAO) recommends the use of digital technologies that boost productivity, as the increased output can help to lower the risk of global food security. Farmers use drones and sensors to improve their farming techniques. Pesticide and fertiliser consumption will decrease in the future, according to this smart agricultural revolution and total efficiency will increase in many folds. In addition to breeding, introduction and selection in the post-green revolution era, smart farming appears to be the gateway of the 3<sup>rd</sup> green revolution in near future in India by utilising these smart farming technologies and instruments. This method, in general, comprises the use of network and communication technology to fulfil specific production goals while simultaneously promoting sustainable agriculture. Continuing to adopt smart farming in agriculture, according to current trends, can help to alleviate the risk of unsustainability in agriculture.

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