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The Internet of Things (IoT) for Sustainable Agriculture

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Abstract

Increasingly, agriculture is becoming more knowledge-intensive. The challenge of feeding the ever-rising population will not be an easy task. Most of the food consumed in developed nations is provided by half a billion small-family farmers. Small-scale farming families play a critical role in increasing food production for our future food and nutritional security. However, they often have limited access to markets, knowledge, new technology and skills, new inputs, emerging value chains, and other opportunities. The development of agricultural research and its effective applications in the agricultural sector through the transfer of extension and advisory services is critical in achieving improved and sustainable agricultural production and productivity growth. Improved access to and availability to information and communication technologies (ICTs), especially cell phones, computers, radio, Internet, and social media, has created many more opportunities for multiformat information gathering, processing, storage, retrieval, management and sharing.

Keywords: IoT, weather, sustainability, agriculture

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8.1 Introduction

Agricultural production depends on many variables, the main factor being weather. Weather varies with space and time; its forecast can also help reduce farm losses by proper agricultural operations management. It is not possible to fully prevent all farm losses due to weather conditions, but it can be reduced to some degree by making changes through timely and reliable weather forecast details. Agromet's weather forecast and weather-based advisories help increase the economic gain of farmers by recommending effective management practices in compliance with weather conditions [3].

The success or failure of the production of agricultural crops is determined primarily by weather parameters. Via its impact on soil and plant growth, the weather manifests its influence on agricultural operations and farm development. A large portion of the overall annual crop losses are because of aberrant conditions. The loss could be reduced by timely and reliable weather forecasting by making changes to the coming weather. With the aid of advanced weather forecasts, agricultural operations may be advanced or postponed for 3 to 10 days. Agricultural forecast useful not only for the efficient management of farm inputs but also contributes to reliable impact assessments [4].

Weather is one of the most significant factors deciding agricultural production's success or failure. It has an impact on any stage of plant growth and development. Any weather variability during the crop season, such as monsoon delay, excessive rains, floods, droughts, too-high or too-low temperature spells, will affect crop growth, and ultimately the yield quality and quantity. With timely and reliable weather forecasts, crop losses can be minimized by doing proper crop management in time. The weather forecast also offers guidance on the selection of crops best suited to the climatic conditions predicted.

The aim of the weather forecast is to inform farmers on the real and expected weather and its effect on the different daily farming operations, i.e., sowing, weeding, pesticide spray time, irrigation scheduling, application of fertilizer, and so on, and overall crop management. Increased agricultural output, reduced losses, reduced risks, reduced input costs, improved yield efficiency, increased productivity in the use of water, labor, and energy, and reduced contamination through judicious use of agricultural chemicals are all benefits of the meteorological forecast. Climate and weather data can be used to make better-informed policy, institutional, and community decisions that reduce risks and increase opportunities, improve the efficient use of scarce resources, and boost crop, livestock, and fisheries production [3].

In agriculture, there are several different types of weather and climate-related threats: limited water resources, drought, desertification, soil erosion, deforestation, hail, floods, early frosts, and so on. Farmers' decision-making processes will be supported by accurate weather and environmental information and advisory services, which will improve their management of relevant agricultural risks. Such services can aid in the development of sustainable and economically viable agricultural systems, as well as the improvement of productivity and quality, the reduction of losses and risks, the reduction of costs, the efficient use of water, labor, and energy, the conservation of natural resources, and the reduction of pollution caused by agricultural chemicals and other age-related pollutants.

The ability of information and communication technologies (ICTs) has opened up new ways of knowledge management over the last decade, which could play a key role in addressing the common challenges of knowledge and technology sharing, exchange, and dissemination. Information and communication technologies are now widely acknowledged as a central factor in the transformation of agricultural extension and information services [5]. Globalization, dynamic market forces, the need for value-added farming, and sustainable use of the natural resource base all necessitate a drastic transformation of agriculture in the developing world. The new agricultural paradigm requires the use of ICTs.

Traditional structures have been used to disseminate agricultural information to farmers in the past, such as literature, posters, radio, and television. In this context, there are several time delays in the transfer of information from research laboratories to farmers. Farmers may depend on extension staff for expert guidance on how to plant the crop. Weather forecasting is one of the most important aspects of farming, because it helps farmers to make the best decisions at the right time. Rather than a set of conventional crop practices, today's farmers need more knowledge of selling rates for local markets, selling intelligence, and precision farming.

Information and communication technologies are seen as a critical component in making such a transition. Information and communication technologies are the most efficient and fast partners for agricultural extension. By improving access to information and exchanging knowledge, ICT-enabled extension systems play a key role in changing the agricultural situation and the lives of farmers. Agricultural extension using ICT opens up exciting possibilities and has the potential to empower farming communities.

8.2 ICT in Agriculture

Information and communication technology is a concept that focuses on utilizing and incorporating information technology (IT) communication systems [3]. Information and communication technology applies to any system or product that allows "electronically recording, storing, transmitting and displaying data and information." This includes the Internet and all hardware and software for computers, including radio, digital television, cellular networks, mobile phones, and satellite systems [6].

Information and communication technology is the global economy's driving force (ICT). It has been recognized as a key development tool for improving citizens' economic and social well-being [1]. Information and communication technology has become a part and parcel of our daily life in this digital age. Without its integration into the knowledge age, countries or regions have no chance of evolving. In addition to opening up new opportunities for economic growth and social progress, the ICT revolution has also created problems and challenges. In the agricultural, industrial and social sectors, it can form and enhance a wide range of developmental applications and affect all sections of society.

For human development, ICT offers unique opportunities. It refers to any electronic means of information collection, retrieval, storage and dissemination. For all attempts to bring about a social shift, communication is important. The advent of ICT has allowed a rapid pace of collaboration, interaction, and data that have had a greater effect on society.

Information and communication technology is a diverse collection of technical tools and resources for knowledge creation, distribution, storage, added value, and management. In particular, advances in ICTs and the Internet have revolutionized the entire field of agriculture, creating new markets, altering the structure of the distribution systems for agriculture, and reengineering all processes [2].

During the last two decades, there has been a great deal of interest in understanding the capacity of ICTs to achieve socioeconomic growth [5]. This resulted in studies in areas, such as agriculture, health, government, financial services, education, and jobs with different ICTs and their implementations. Many of these programs clearly show the tremendous potential of ICTs to enhance the quality and effectiveness of delivering accurate information to rural communities.

In the recent past, ICTs have played an important role in promoting the management of skills and, as a result, fostering innovation in the agriculture sector [7]. Providing localized and customized advisory services, assisting in information management, enabling extension actors to collaborate on innovation, enabling farmers and others to "gain a voice" through social media, and supporting farmers, extension practitioners, and other AIS actors' capacity development are all examples of ICT-based extension advisory methods. Information and communication technologies not only encourage scientists and extension practitioners to exchange knowledge but also enable farmers to connect better returns to the market and consumers. It also provides farmers with the ability to share their farming practices and challenges. Information and communication technology needs to be harnessed by all the players for agricultural production. Technological applications can hit millions of farmers, stakeholders, and rural areas and serve as a catalyst for social change and for food security.

8.3 Internet of Things in Agriculture and Allied Sector

The global recession's revival has created ripples across both developed and emerging economies. To ensure global food security, the agricultural sector would have to be even more productive and resilient. Together, modern-day agriculture and society demand increased food production to feed the global population. New innovations and solutions are being applied in the agricultural sector to provide an effective alternative to collecting and processing data while increasing net productivity.

At the same time, the alarming effects of climate change and the escalating water crisis necessitate the creation of new and improved methodologies for food and agricultural fields in the modern age. In terms of farm size, technology, trade, government policies, and so on, farmers in underdeveloped and developing countries are significantly disadvantaged. Information and communication technologies can help farmers solve some of their problems. To accomplish this goal, automation and smart decision making are also becoming more important [7]. The Internet of Things (IoT), pervasive networking, ad-hoc wireless and sensor networks, radio frequency identifiers, cloud computing, remote sensing (RS), and so on, are becoming increasingly common in this regard [1, 4].

After the World Wide Web (of the 1990s) and the mobile Internet, we are now heading to the third and probably most "disruptive" stage of the Internet revolution, the "Internet of Things (IoT)," also known as "Ubiquitous Computing" (of the 2000s) (Figure 8.1) [8]. Agriculture, health care, retail, transportation, the environment, supply chain management, infrastructure monitoring, and other fields are all impacted by IoT implementations.

In the field of agriculture, we promote sustainable agriculture and productivity improvement through the use of IoT, and the integration of IoT in

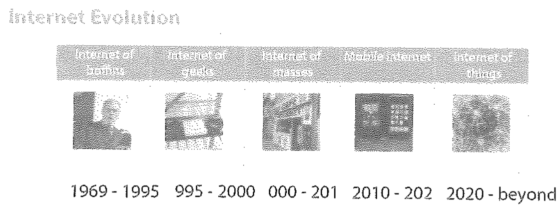

Figure 8.1 Internet evolution. Source: [2].

agriculture pushes for smart agriculture [9, 10]. Agricultural applications include soil and plant monitoring, greenhouse environment monitoring and control systems, food supply chain monitoring, animal monitoring, and so on [10]. Precision farming equipment with wireless links to data from remote satellites and ground sensors may take crop conditions into account and adjust how each part of a field is farmed, such as by applying additional fertilizer to areas that need more nutrients [4, 10, 11].

The networking of things or physical objects must be cost-effective and useful for end users in order for IoT to be accepted and widely adopted [1, 3]. For emerging and underdeveloped economies, the Global ICT Standardization Forum has defined the following potential benefits of IoT: (i) improved efficiency, visibility, and scalability; (ii) better and more cost-effective operation; (iii) consistency of physical flows and accurate status details; and (iv) improved quality, precision, agility, and automation.

The IoT is a worldwide network of interconnected computers [12]. Pervasive networking, computation, and environmental knowledge are all part of it. Internet of Things is a vision in which "stuff," especially everyday items, such as all home appliances, furniture, clothes, vehicles, roads, and smart materials, can be read, recognized, found, addressed, and/or controlled through the Internet. This will serve as the foundation for a wide range of emerging technology, including energy management, transportation safety systems, and building security.

The Internet of Objects will connect the world's products in a sensory and intelligent way by combining technological developments in object recognition ('tagging items'), sensors and wireless sensor networks ('feeling stuff'), embedded systems ('thinking things'), and nanotechnology ('shrinking things') [8]. The following are some of the benefits of IoT applications in agriculture:

1. improved efficiency of inputs for use (soil, water, fertilizers, pesticides, etc.),
2. reduced production costs,

3. augmented profitability,
4. sustainability,
5. safety in food,
6. environmental security.

The IoT has the potential to transform how people live around the world [12]; we now have more efficient factories, connected cars, and smarter cities, all thanks to an integrated IoT system [13].

By 2050, the world's population will have risen to 9.6 billion people [14]. As a result, the agricultural industry must embrace IoT to feed this massive population. The need for more food necessitates the resolution of issues, such as increasing climate change, extreme weather, and the environmental consequences of intensive agricultural practices. Smart farming can help farmers minimize waste and increase productivity by using IoT technologies. This may be because of the amount of fertilizer used in relation to the number of trips taken by farm vehicles. The term "smart farming" refers to a high-tech food-growing system that is both clean and healthy for the general public [11]. It is also the introduction and application of modern ICTs to agriculture (Figure 8.2).

Internet of Things agriculture applications include precision farming, agriculture drones, livestock monitoring, and smart Greenhouses (Figures 8.3 and 8.4).

8.3.1 Precision Farming

Precision farming is a method or system for raising livestock and crops that makes the process more precise and supervised. The use of IT and items, such as sensors, autonomous vehicles, automated hardware, control

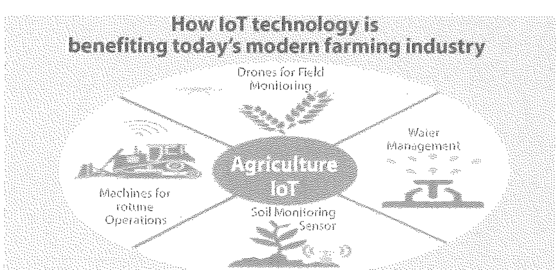

Figure 8.2 IoTs and today's innovative farming industry. Source: data-flair.training.

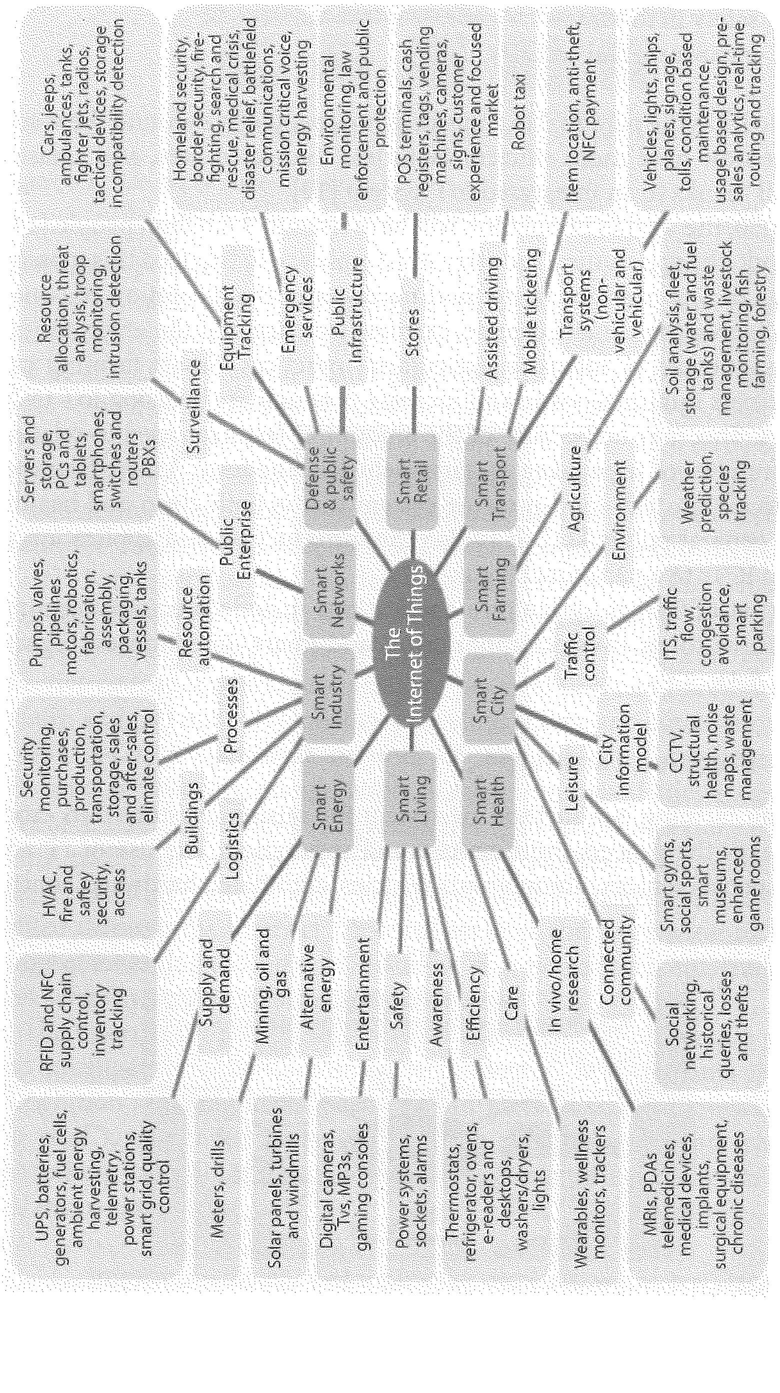

Figure 8.3 IoT proliferation. Source: [2].

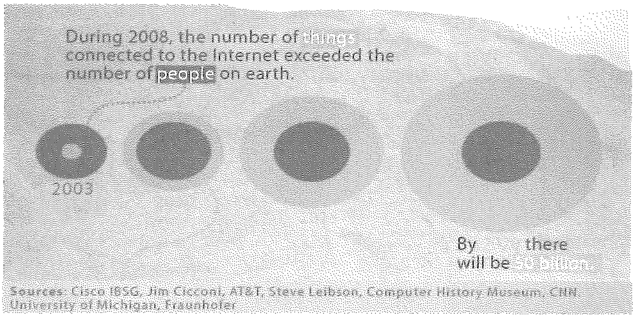

Figure 8.4 People-to-IoT ratio. Sources: Cisco IBSG, Jim Cicconi, AT&T, Steve Leibson, Computer History Museum, CNN. University of Michigan, Fraunhofer; [2].

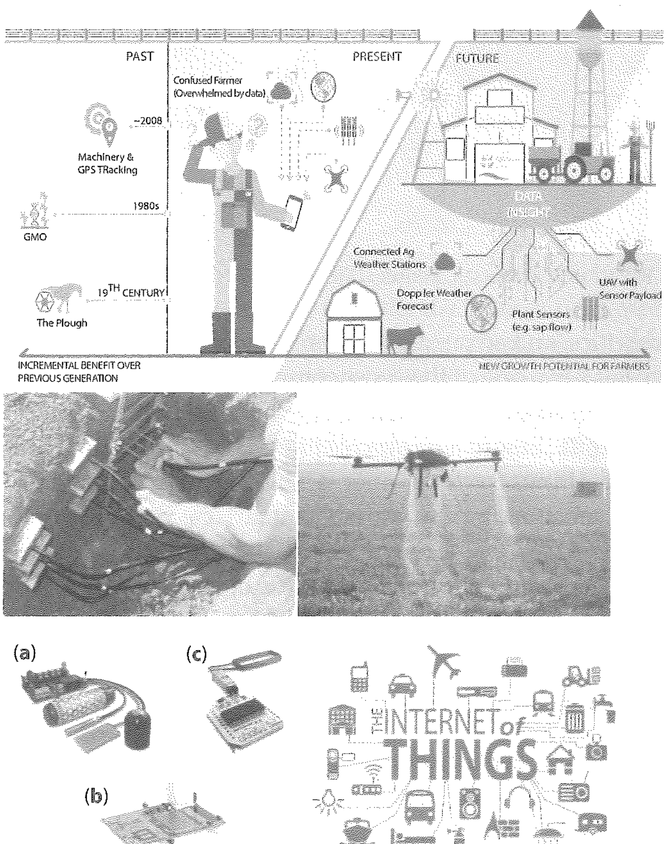

Figure 8.5 The future of agriculture with IoT and smart devices (a-c). Source: [2].

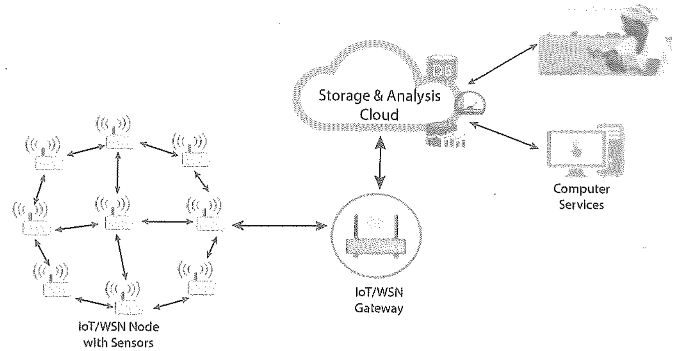

Figure 8.6 The general system architecture. Source: [2].

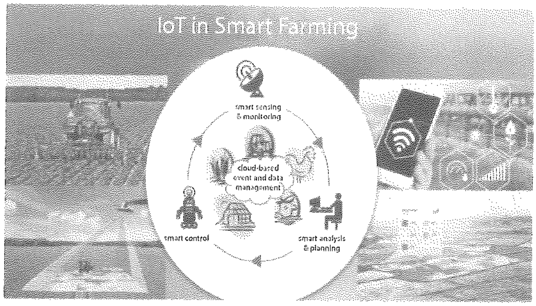

Figure 8.7 IoT in smart farming. Source: [2].

systems, robotics, and so on, are key components of this strategy. Precision agriculture has been one of the most common IoT applications in the agricultural sector in recent years, with a large number of organizations around the world using it (Figure 8.5).

Internet of Things systems offer a variety of products and services, including soil moisture probes, variable rate irrigation (VRI) optimization, virtual optimizer PRO, and more. The VRI optimization is a method for maximizing the profitability of irrigated crop fields with soil variability, increasing yields and increasing water quality (Figures 8.6 and 8.7).

8.3.2 Agriculture Drones

Agricultural drones are a great example of IoT applications in agriculture (Figure 8.8). Agriculture is one of the most important sectors in which drones can be used today. Drones, both ground-based and aerial-based, are being used in agriculture in a variety of ways, including crop health assessment, irrigation, planting, and soil and field analysis.

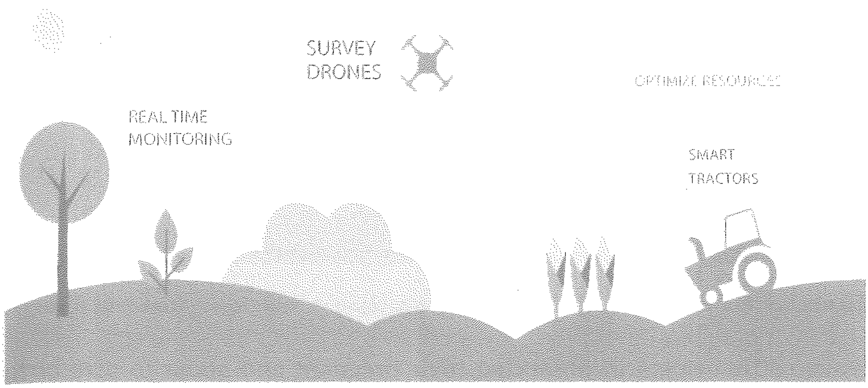

Figure 8.8 Agricultural drones. Source: [2].

Drones have many benefits, including ease of use, time savings, crop health imaging, interactive Geographic Information System (GIS) mapping, and the potential to increase yields. Drone technology will offer the farming industry a high-tech makeover by using strategy and preparation based on real-time data collection and processing. Farmers may use drones to survey specific fields by entering specific data. Choose if the field data are extracted at a higher altitude or at a lower ground resolution. The data collected by the drone can be used to make useful observations on various factors, such as plant counting and yield prediction, plant health indices, plant height estimation, canopy cover mapping, nitrogen content in wheat, drainage mapping, and so on. During the flight, the drone collects thermal, multispectral, and visual data and photographs before landing in the same location from which it took off.

8.3.3 Livestock Monitoring

Farmers may use IoT applications to collect data on their livestock's location, well-being, and health [15, 16]. They will use this information to determine the health of their livestock, such as detecting infected animals and isolating them from the rest of the herd, preventing the disease from spreading to the rest of the herd. The ability of ranchers to use IoT-based sensors to locate their cattle reduces labor costs significantly.

JMB North America, a company that provides cattle farmers with cow tracking solutions, is an example of an IoT system in use by a company (Figure 8.9). Among the many options offered, one of the solutions is to

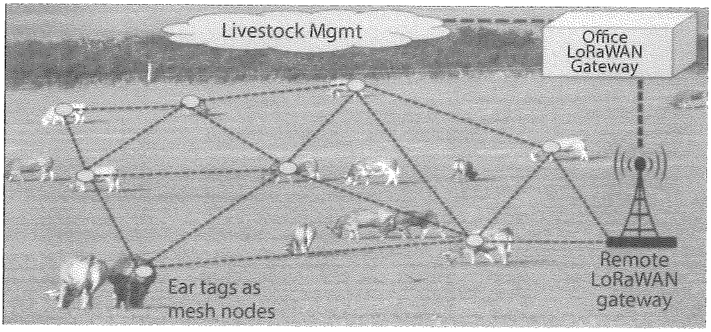

Figure 8.9 IoT in livestock management. Source: [2].

assist cattle owners in observing their pregnant and about to give birth cows. A sensor-powered battery is ejected from them as their water splits. The rancher or the herd's manager will then receive the information. As a result, the sensor aids farmers in concentrating more.

8.3.4 Smart Greenhouses

Greenhouse farming is a method of increasing grain, fruit, and vegetable yields. Greenhouses regulate environmental parameters in one of two ways: manually or through a proportional control mechanism.

Manual intervention, on the other hand, has disadvantages, such as production loss, energy loss, and labor cost, making these methods less effective. Via IoT-embedded systems, a smart greenhouse not only intelligently manages but also regulates the environment, obviating the need for human intervention (Figure 8.10) [9, 10]. Different sensors that calculate environmental parameters according to the plant requirement are used to monitor the environment in a smart greenhouse. As it uses IoT to connect, a cloud server is installed to allow remote access to the computer. The greenhouse's cloud server aids in data analysis and the implementation of a control action.

This design provides farmers with optimal to cost-effective solutions with minimal to almost no manual interference.

Illuminum Greenhouses, an Agri-Tech greenhouse company that uses technology and the Internet of Things to provide services, is one example. It creates modern and inexpensive greenhouses by using solar-powered IoT sensors. The greenhouse status and water consumption can be monitored using these sensors, which send SMS updates to the farmer through an online portal. Temperature, pressure, humidity, and light levels are all measured by sensors in the greenhouse IoT system.

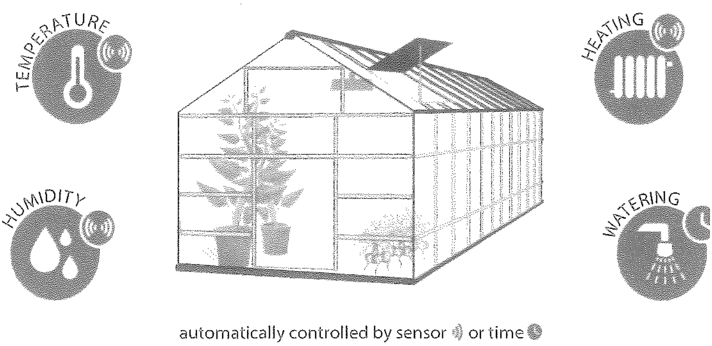

Figure 8.10 Smart greenhouse. Source: [2].

8.4 Geospatial Technology

Geospatial technology refers to the simulation, calculation, and study, using specialized equipment, of the characteristics of the earth or other natural phenomenon viewed from space. The RS-GIS and GPS are the fundamental components involved in this technology that enable the creation of a Decision Support System (DSS) with regard to the dissemination of data or information produced. For the visual analysis of geospatial features using satellite sensors and the interpretation of image data, space-based technology, such as RS, has been adopted for this purpose. Geospatial characteristics and their suitable locations provide a forum for companies in different fields to develop, and many organizations are interested in using this technology to improve their business or research work.

In any given geographical location, produced and stored data regarding geospatial characteristics have a strong visual impact displayed through maps, and maps play a vital role in monitoring and quantifying change over time scale over this problem. The technology of RS and GIS is directly and indirectly involved in developing geospatial information and geo-database management. The RS-GIS has provided a single window forum for the dissemination of geospatial features relevant to farmer advisory services under the ICT mode.

8.4.1 Remote Sensing

The collection of data about an object or a phenomenon using RS requires no physical contact with the object (Figure 8.11). It's a phenomenon with a wide range of applications, including photography, surveying, geology,

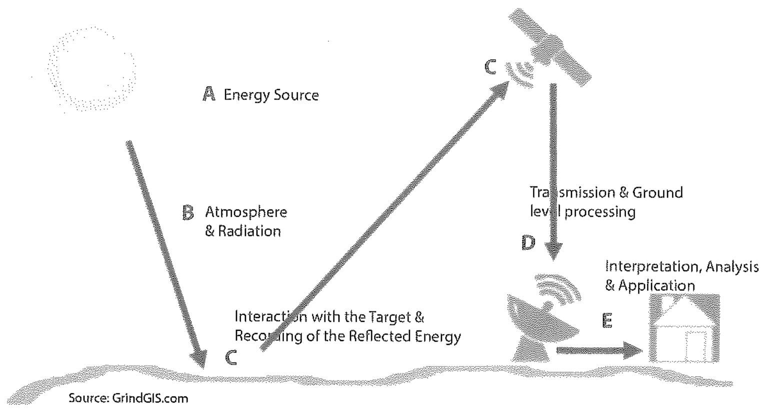

Figure 8.11 Remote sensing. Source: GrindGIS.com.

forestry, and more. So, what exactly is RS? The art and science of collecting knowledge about the surface of the earth without making any direct interaction with it is RS. This is achieved by detecting and recording energy that is reflected and released.

The agricultural sector has a wide range of RS applications. The following is a list of these applications, referred to as digital satellite image processing in this case:

a. **Crop identification:** RS has also played an important role in crop identification, especially in cases where the crop being observed is mysterious or has some mysterious characteristics. Crop data are obtained and transported to laboratories, where various aspects of the crop, including crop culture, are examined.
b. **Field acreage estimation:** RS has also proven very useful in estimating the amount of agricultural land on which a crop has been planted. This is usually a repetitive process if performed manually because of the large sizes of the lands being measured.
c. **Predictive planting and harvesting dates:** Because of the predictive nature of RS technology, farmers can now use RS to observe a range of variables, such as weather patterns and soil types, to forecast the planting and harvesting seasons of each crop.
d. **Crop condition assessment and stress detection:** RS technology plays an important role in determining each crop's

health status, as well as the degree to which it has withstood stress. This knowledge is then used to determine the crop's quality.

e. **Drought monitoring:** Weather patterns in a given area, including drought patterns, are tracked using RS technology. The data can be used to forecast rainfall patterns in a given region, as well as to determine the time difference between current precipitation and the next precipitation, which aids in drought tracking.
f. **Crop yield modeling and estimation:** RS often aids farmers and experts in predicting the estimated crop yield of a given farmland by estimating crop quality and farmland extent. This information is then used to estimate the crop's average yield.
g. **Crop production forecasting:** RS is used to forecast crop production and yield over a given area, as well as to decide how much of the crop will be harvested under specific conditions. Researchers will forecast the amount of crop that will be grown in a given farmland over a given period of time.
h. **Crop damage and development assessment:** RS technology may be used to access farmland in the event of crop damage or crop growth and to determine how much of the donated crop was lost and how the remaining crop on the farm is developing.
i. **Cropping systems and horticulture research:** RS technology has also been useful in analyzing various crop planting systems. This technology has primarily been used in the horticulture industry to examine flower growth trends and make predictions based on the findings.
j. **Soil moisture estimation:** Without the aid of RS technology, soil moisture calculation can be challenging. Remote sensing provides data on soil moisture, which aids in determining the amount of moisture in the soil and, as a result, the type of crop that can be grown there.
k. **Irrigation monitoring and control:** RS offers information on the amount of soil moisture. This expertise is used to determine whether a soil is deficient in moisture and to prepare irrigation needs for that soil.
l. **Soil mapping:** One of the most popular and important applications of RS is soil mapping. Farmers may use soil

mapping to determine which soils are appropriate for which crops and which soils need irrigation, as well as which soils do not. This expertise is useful in precision agriculture.

m. **Land cover and land loss mapping:** Experts have used RS to chart a particular region's land cover. Experts may now tell which areas of the land have been degraded and which parts are still intact. This also allows them to take measures to reduce soil degradation.
n. **Identification of problematic soils:** RS has also played a critical role in identifying problematic soils that have a difficult time sustaining maximum crop yield during the planting season.
o. **Detection of crop nutrient deficiency:** RS technology has also aided farmers and other agricultural experts in determining the extent of crop nutrient deficiency and developing solutions to increase the amount of nutrients in crops, thus increasing overall crop yield.
p. **Crop yield forecasting:** Using crop data, such as crop quality, soil and crop moisture levels, and soil crop coverage, RS technology can provide accurate estimates of expected crop yield during the planting season. When all of this information is combined, the crop yield can be estimated fairly accurately.
q. **Precision agriculture:** RS has played a key role in precision agriculture. Precision agriculture has resulted in the cultivation of healthy crops that ensure optimum harvests for farmers over a set period.
r. **Crop intensification:** RS may be used to collect critical crop data, such as crop patterns, crop rotation needs, and crop diversity, over a given soil for crop intensification.
s. **Flood mapping and monitoring:** Farmers and agricultural experts may use RS technology to map out flood-prone areas, as well as areas with insufficient drainage. This experience could then be put to use in the event of a flood disaster.
t. **Satellite meteorology:** RS technology is useful for the generation of various weather data products. Satellite-derived rainfall products are widely used for a variety of land and water management applications.
u. **Water resource mapping:** RS is useful for mapping water supplies through farmland that can be used for agriculture.

Farmers may use RS to determine what water sources are available for use on a specific piece of land and if the supplies are adequate.

v. **Climate change monitoring:** RS technology is critical for monitoring climate change and keeping track of climate conditions that influence where crops can be grown.
w. **Farmer compliance monitoring:** Agricultural experts and other farmers depend on RS to keep track of all farmers' farming practices and ensure compliance. This ensures that all farmers follow the proper procedures when planting and harvesting crops.
x. **Soil management practices:** RS technology is critical for determining soil management practices based on data obtained from farms.
y. **Air moisture estimation:** RS technology is used to estimate air moisture, which is used to assess the humidity of an area. The type of crops that can be grown in the area is determined by the humidity level.
z. **Land mapping:** RS aids in the mapping of land for various uses, including crop production and landscaping. The mapping technology used in precision agriculture, where unique land soils are used for specific purposes, is beneficial.

8.4.2 Geographic Information System

Is a computer system that collects, stores, modifies, evaluates, manages, and displays all types of spatial or geographical data (Figure 8.12). End users can use the GIS framework to perform spatial queries, analyze and edit spatial data, and generate hard-copy maps. Geographic Information System is simply an image that is referenced to the Earth or synchronized with x and y coordinates, and the attribute values are stored in a table. These x and y coordinates are dependent on a variety of projection systems, and there are several different types of projection systems. The majority of the time, GIS is used to build and print maps. In order to perform the basic task in GIS, layers are mixed, modified, and created. So, what exactly is GIS? "A GIS allows us to visualize, query, evaluate, and interpret data to better understand relationships, patterns, and trends."

"GIS can be used to address location-related questions like 'What is located here?' or 'Where can I find unique features?'" The GIS user can extract value from the map, such as how much forest land is shown on the land use map. This is accomplished by using the query builder function.

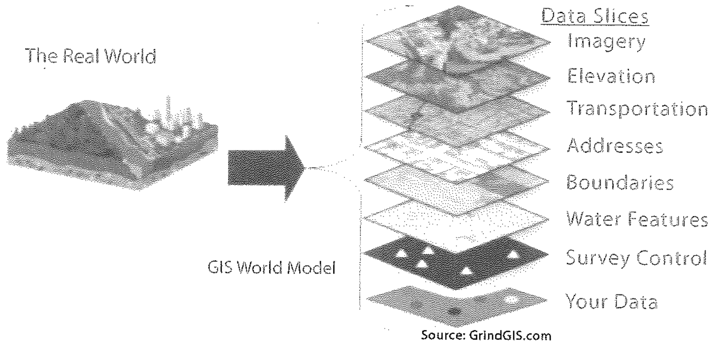

Figure 8.12 GIS and the agro-ecology. Source: GrindGIS.com.

The ability to combine different layers to display new information is the GIS's next major feature. For example, you can combine elevation data, river data, land use data, and other data to view information about the area's landscape. You can tell from the map where the highlands are or where the best spot to build a house with a view of the river is. To find new knowledge, GIS helps.

Data visualization: The GIS software can show the geographical data stored in the databases.
Combining data: Layers are combined to create a map of desire.
Query: To look for a value in the layer or to run a geographic query.

Geographic Information System is a piece of software that allows users to create interactive queries, analyze spatial data, edit data, chart, and present the results of all of these operations in a more general context. GIS technology is becoming an increasingly valuable tool for combining various maps and RS data to generate various models that can be used in real-time situations.

The geographical information system is a science that employs geographical concepts, implementations, and systems [15]. The GIS can be used for analysis, resource management, asset management, environmental impact assessment, urban planning, cartography, criminology, history, advertising, marketing, and logistics. Agricultural planners may use geographical data to decide on the best locations for location-specific crop planning by integrating soil, topography, and rainfall data to assess the size and position of biologically suitable areas. Land-ownership overlays, transportation, infrastructure, labor supply, and distance from market centers can all be factors in the final product. Geographic Information System use has the following advantages:

i. better political decision-making by individuals,
ii. use layered data to help you make better decisions,
iii. people are more engaged as a result of a better structure,
iv. support to recognize neighborhoods where infrastructure is at risk or missing,
v. helps to recognize concerns around criminology,
vi. better natural resource management,
vii. good coordination in an emergency,
viii. because of better judgment, cost savings,
ix. seeing various types of developments within the group,
x. planning for shifts in demography.

8.4.3 GPS for Agriculture Resources Mapping

GPS stands for Global Positioning System. In the recent past, this technology has progressed impressively and has diverse applications throughout a range of industries (Figure 8.13). One of the main areas where GPS has found interest is in precision farming and agriculture. The GPS has become increasingly popular as a guidance receiver and navigation app that tells us where we are and how to get from point A to point B in recent years. This has also been employed in the development of digital maps. However, GPS

Figure 8.13 GPS application in the farm field. Source: GrindGIS.com.

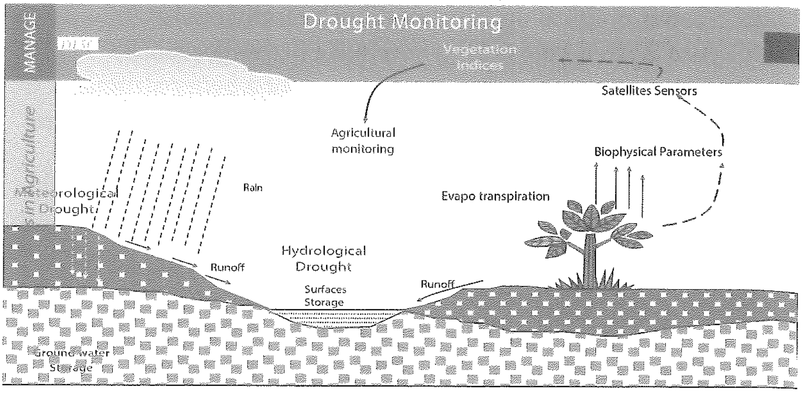

Figure 8.14 Drought monitoring. Source: [2].

applications are used by a variety of organizations, as well as people for different purposes.

Pilots, surveyors, fishermen, boat captains, military officers, and scientists, among others, will find it useful. Aside from the standard GPS on our phones, other highly advanced applications are extremely powerful and are used for specific tasks in a variety of industries.

Farmers have a specific planting, weeding, and harvesting season, and because of this, they install GPS receivers on their tractors and other farming equipment (Figure 8.14). This allows them to map their plantations and ensure that they return at the same time the following season to plant or weed. This technique is especially effective in foggy, low-visibility seasons because the device continues to operate as guided by its GPS rather than by visual reference. Furthermore, because of its high precision, it can be used to locate soil sample mapping locations, allowing farmers to classify areas with agriculturally suitable soils. We look at some of the most important agricultural GPS applications and how they have changed the way farmers operate.

i. **Soil profiling:** GPS provides the data needed to accurately assess soil variability and determine if a certain type of soil is appropriate for growing a specific crop. Soil sampling is often used in soil profiling to distinguish between viable and nonviable soils.
ii. **Weed location:** Using linear sampling methods, GPS can be used to locate weed patches in vast areas of land. Weed inhibits a crop's productive growth and, as a result, reduces subsequent yields over time.

iii. **Accurate planting:** When preparing the planting of a given crop, GPS is also useful. Depending on the soil type, each seed has special spacing and depth necessary. It is easier to say what spacing a given seed needs and at what depth the seed should be planted using GPS in order to return full yields.

iv. **Determination of planting ratios:** In deciding the planting ratios of seeds, GPS may also be used. Some seeds have unique spaces between them, whereas those with other seeds may be planted. In deciding the ratio of this sort of planting, GPS helps.

v. **Yield map creation:** In the creation of yield maps for specific crop types, GPS plays an important role. For example, during harvesting, GPS can be used to map the expected yields of a given crop from a given piece of land based on the land's characteristics and the seed's characteristics.

vi. **Harvesting:** GPS plays an important role in determining when an area of a farm is ready to be harvested and how it will be harvested. The GPS will also provide an estimate of the size of the region being harvested as well as the estimated returns from the area.

vii. **Locating a yield map:** GPS can be used to locate a yield map by installing a GPS receiver on farm machinery and then collecting data.

viii. **Environmental control:** using herbicides or pesticides based on each square meter's capacity reduces the amount of pesticide used in the application. This aids the soil in absorbing all of the contaminants, lowering the risk of runoff.

ix. **Farm planning:** In the planning of ready-to-plant agricultural property, GPS plays an important role. GPS will provide the overall size of the field and assist in deciding what crop will be planted on what portion of the farmland based on a variety of elements such as soil and crop characteristics.

x. **Land mapping:** GPS provides a precise estimate of the land that will be used for agriculture. Experts will be able to tell which parts of the field will be used for agricultural purposes and which will be used for nonagricultural purposes using this method.

xi. **Soil sampling:** Soil sampling is one of the most important applications of GPS in agriculture. Knowing what kind of soil is available on a given piece of farmland is critical, as it will influence the kind of crop that will be planted there.

xii. **Crop scouting:** GPS allows for precise mapping of a region, which aids in the scouting of crops grown in that area. Experts will use this to determine the nature and type of crops that grow in a given location and help to improve the quality of that crop.

xiii. **Yield mapping:** After a crop has been planted and is ready for harvesting, GPS may be used to estimate the yield of a given farmland. This can be accomplished by aerial mapping, which allows experts to estimate the volume of a yield based on the crop area covered.

xiv. **Crop yield production technique correlation:** GPS can be used to calculate the relationship between the crop yields over time and the production technique used over a given piece of land. This knowledge can then be used to assess the effectiveness of a process.

xv. **Soil property mapping:** GPS plays an important role in evaluating the soil property of a given soil in order to assess its variability and suitability for a given crop (Figure 8.15). It also enables researchers to decide what type of soil

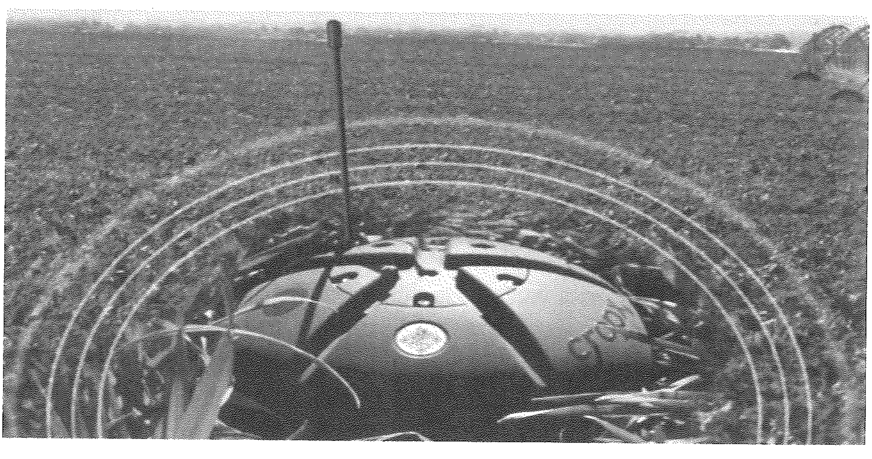

Figure 8.15 Crop X is a hardware and software system that measures soil moisture, temperature, and electrical conductivity and sends the information to the cloud, where it can be accessed from any mobile or fixed device. Source: [2].

is present in a given farmland region and which region is best suited for a particular crop.

xvi. **Machinery location:** GPS makes it easier to find some farm machinery on a big plot of land. The farmer does not need to physically go out and find farm equipment, particularly if the number is large. GPS may be used to pinpoint the precise position of farm equipment.

xvii. **Machinery direction:** Technology has necessitated the use of autonomous farm machinery in farming. These devices are driven by GPS to determine the direction in which the seeds are placed as well as the spacing between each seed.

xviii. **Determining which areas are suitable for cultivation:** In a given agricultural zone, GPS plays an important role in determining which areas are suitable for cultivation. Aerial mapping of the under-cultivated area and analysis of soil samples was used to determine the viability of the soil.

xix. **Geographical classification of growing areas based on various characteristics:** GPS may be used to classify different growing areas based on various characteristics such as soil types and terrain maps. Areas that are not suitable for cultivation can be identified and alienated, whereas those that are suitable can be established.

xx. **Determination of water supply in a specific area:** GPS has been used to assess the availability of water or water supplies in a specific area. Water bodies, such as rivers and canals, can be easily detected using GPS.

xxi. **Identification of irrigated and nonirrigated crops:** GPS may also be used to locate areas where irrigated and non-irrigated crops coexist. This helps create a profile between irrigated and nonirrigated crops to allow for comparisons.

xxii. **Detection of swamps and other waterlogged areas:** GPS can be used to identify swampy and waterlogged areas that aren't appropriate for certain crop types. This aids in determining if certain forms of land are ideal for certain crops but not for others.

xxiii. **River mapping:** GPS aids in the creation of a map of all rivers within a given area, resulting in a water flow profile for the region. Farmers and researchers may be able to detect the presence of rivers and assist in the selection of crops to be grown in that region.

xxiv. **Land use in the locality:** GPS may be used to map land use in a particular region. It is easier to say what portion of the land has been cultivated and what portion has been left barren using GPS.

xxv. **Contour mapping:** In cases where the land is irregular, GPS has become extremely useful in determining the contours within a specific locality. This is because of the fact that some crops will not thrive in contoured lands, while others will thrive.

xxvi. **Mapping of irrigation systems such as dams and canals:** In cases where a land needs to be irrigated, GPS can assist in identifying certain irrigation systems such as dams and canals. It will be more convenient because the necessary water will be used to irrigate the land.

xxvii. **Meteorological mapping, such as climate patterns:** GPS plays an important role in deciding the type of crop that can grow in a given region while mapping those climatic conditions. Personnel Mapping: At certain times of the day, GPS can be useful in determining the number of jobs on a given piece of farmland. If a farmer wants to quantify the productivity of farm employees, this is crucial.

xxviii. **Plantation mapping:** GPS can assist in the development of a plantation map as well as the calculation of a plantation's crop yields.

xxix. **Water bodies mapping:** GPS can be used to map identified water bodies within a given area in order to determine the viability of crop growth and yields in a given region.

8.5 Summary and Conclusion

Extension agents may use IT-enabled tools to help the farming community in a number of ways, allowing them to become more reliable and productive extension managers. One or more business processes are distributed to an external service provider through ICT-enabled services. The service provider owns, manages, and administers the selected processes based on defined and measurable performance measures. The core ICT-enabled facilities and instruments in our country have the ability to produce creative, efficient, and learner-centered extension services. This would have a major impact on farmers, rural residents, and the agricultural economy as a whole.

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