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## 1. AGRICULTURA METEROLOGY

# Geospatial Technologies in Agriculture: Integrating Remote Sensing, GIS, UAVs, Artificial Intelligence and Geospatial Foundation Models for Precision and Sustainable Farming

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### Abstract

Agriculture is increasingly required to produce more food while facing climate variability, declining natural resources, soil degradation, water scarcity, labour constraints and increasing production costs. Geospatial technologies have emerged as important tools for addressing these challenges by providing spatially explicit, timely and multi-temporal information for agricultural decision-making. Geographic Information Systems (GIS), Global Navigation Satellite Systems (GNSS), satellite remote sensing, unmanned aerial vehicles (UAVs), proximal sensors, Internet of Things (IoT), cloud computing and artificial intelligence (AI) are transforming conventional agricultural management into data-driven precision agriculture. Remote sensing provides information on crop growth, vegetation condition, soil properties, water availability, pests, diseases and crop stress, whereas GIS enables the integration, analysis and visualization of these spatial datasets. High-resolution satellite missions and UAV platforms have further improved the spatial and temporal monitoring of individual fields.

Recent developments have expanded the role of geospatial technologies from simple mapping and monitoring toward predictive and prescriptive agricultural management. Machine learning and deep learning are increasingly being used for crop classification, yield prediction, disease detection, weed identification, irrigation scheduling and soil assessment. In 2025–2026, the emergence of geospatial foundation models represents another important development, with researchers investigating whether pretrained models can provide transferable representations for agricultural applications.

However, challenges remain concerning data quality, interoperability, computational requirements, farmer accessibility, privacy, regional transferability and the validation of AI-based models. Geospatial technologies therefore need to be integrated with field observations, indigenous knowledge and agronomic expertise rather than being considered as stand-alone technologies. This chapter discusses the evolution, current applications and future prospects of geospatial technologies for precision, climate-smart and sustainable agriculture.

**Keywords:** Geospatial technology; Remote sensing; GIS; UAV; Precision agriculture; Artificial intelligence; Machine learning; Geospatial foundation models; Crop monitoring; Sustainable agriculture

### 1. Introduction

Agriculture is a highly spatially variable activity. Soil fertility, moisture availability, crop growth, pest incidence, nutrient requirements and yield can vary considerably within the same agricultural field. Conventional agricultural management generally applies uniform quantities of seed, fertilizer, irrigation water and pesticides across large areas. Although this approach is simple, it may result in inefficient resource utilization and increased production costs. Precision agriculture attempts to overcome this limitation by identifying spatial and temporal variability and applying management practices according to site-specific requirements.

Geospatial technologies have become a fundamental component of this transition. The integration of remote sensing, GIS, GNSS, UAVs and field sensors enables agricultural researchers and farmers to collect, analyse and

visualize information at different spatial and temporal scales. Satellite-based remote sensing can provide repeated observations over extensive agricultural regions, while UAVs can acquire centimetre-level imagery for individual fields. GIS provides the framework for integrating these datasets with soil, weather, topographic, crop and socioeconomic information.

The importance of remote sensing for precision agriculture was comprehensively demonstrated by Sishodia et al. (2020), who described applications in crop monitoring, irrigation management, nutrient management, disease and pest management and yield prediction. The increasing availability of high-resolution satellite imagery has significantly expanded these applications. Similarly, Sentinel-2 imagery has become particularly valuable because its combination of spatial, spectral and temporal characteristics supports crop monitoring and precision agricultural applications.

Geospatial information is particularly valuable because agricultural decisions are inherently location dependent. GIS can combine satellite-derived vegetation indices with soil maps, digital elevation models, rainfall information, irrigation infrastructure and field boundaries. Such integration allows the generation of management zones and prescription maps for variable-rate application of fertilizers, irrigation and crop protection products.

The development of UAV technology has further improved agricultural monitoring. UAV-mounted RGB, multispectral, hyperspectral and thermal sensors can provide very high-resolution information about crop canopy structure, plant health, water stress and nutrient deficiencies. Recent research has demonstrated the use of UAV imagery combined with geospatial cloud computing for crop mapping in smallholder farming systems. Hyperspectral sensing is also increasingly being investigated because its numerous narrow spectral bands can provide detailed information about crop biochemical and biophysical characteristics.

Another major development is the integration of geospatial data with artificial intelligence. Machine-learning algorithms such

as random forests, support vector machines and gradient boosting can classify crops and estimate soil and crop characteristics. Deep-learning approaches, including convolutional neural networks and transformer-based architectures, are increasingly used for image classification, segmentation, crop disease detection and yield prediction. A recent review reported that agricultural remote sensing is increasingly connected with AI-based analysis and decision-making for precision agriculture.

The field is now moving toward a further stage involving **geospatial foundation models**. These models are trained on large quantities of Earth-observation data and have the potential to provide reusable representations for multiple agricultural tasks. Research published in 2026 has begun benchmarking models such as Prithvi, SpectralGPT and SatMAE for agricultural crop segmentation and change detection. However, results also indicate that model performance can decline substantially when models are transferred to geographically different regions, highlighting the importance of regional validation and representative training data.

Recent literature also emphasizes that geospatial technology should not be viewed simply as a method of producing maps. Its real value lies in transforming spatial information into actionable agricultural decisions. The integration of remote sensing, GIS, IoT and machine learning can support variable-rate fertilizer application, irrigation scheduling, pest and disease management, crop forecasting, land-use planning and climate-risk assessment. A 2024 review of remote sensing and GIS in precision agriculture identified high-resolution satellite and drone imagery, proximal sensing, real-time prescription modelling and machine-learning-based predictive analytics as important research directions.

The technology is also becoming increasingly relevant to developing countries and smallholder agriculture. Precision agriculture has traditionally been associated with expensive equipment and large commercial farms; however, small UAVs, mobile applications, cloud platforms, open satellite data and service-based technology models are creating opportunities for smaller farms. Recent literature highlights UAVs, IoT,

mobile applications and data science as important opportunities for expanding precision agriculture in developing countries, although investment, technological accessibility and farmer adoption remain important constraints.

In India, geospatial technologies have considerable potential for crop acreage estimation, crop condition assessment, drought monitoring, irrigation management, soil resource mapping, crop insurance, yield estimation and agricultural planning. The technology can support both farm-level decision-making and regional agricultural policy. Recent Indian applications also demonstrate increasing integration of GIS, satellite imagery, UAV surveys and AI analytics for agricultural monitoring and resource management.

The next generation of agricultural geospatial systems is therefore likely to be characterized by the convergence of Earth observation, GIS, UAVs, IoT, cloud computing, artificial intelligence and foundation models. Such systems can provide near-real-time information and increasingly automated decision support. Nevertheless, successful implementation will require attention to data standards, ground validation, affordability, digital literacy, connectivity, privacy and model reliability.

Overall, geospatial technologies provide a powerful scientific framework for developing precision and sustainable agricultural systems. Their future significance will depend not only on improvements in sensors and algorithms but also on the ability to convert complex geospatial information into affordable, understandable and locally relevant recommendations for farmers. The integration of technological innovation with agronomic knowledge, field observations and farmer participation will be essential for achieving resilient, resource-efficient and climate-smart agriculture.

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## 2. HORTICULTURE

### Standardization of Production Technology for Kachri in Dryland Agriculture

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#### Introduction

The native cucurbit vegetable known as kachri (*Cucumis callosus* (Rottl.) Cogn.) is mostly grown in northwest India's dry and semi-arid areas, especially Rajasthan. It is prized for its resistance to drought, capacity to adapt to marginal soils, and traditional culinary use in both fresh and dried forms. Kachri has becoming more significant as a climate-smart crop for dryland horticulture because of its ability to withstand severe weather (Yadav and yadav, 2010).

#### Climate and Soil Requirements

Kachri is a warm-season crop well suited to hot and dry climates. It can withstand high temperature stress better than many farmed cucurbits and thrives at temperatures between 25 and 35 °C. The crop may thrive in low-fertility soils with a pH of 6.5 to 8.0, although it prefers sandy loam to loamy soils with adequate drainage (pareek and sharma, 1993).

#### Varieties and Genotypes

Traditionally, local landraces chosen by

farmers over many generations have been the foundation of kachri farming. The ICAR–Central Institute for dry Horticulture (CIAH), Bikaner, has improved choices such AHK-119, AHK-200, and AHK-116 for increased production, consistent fruit size, and adaptation to dry settings (ICAR–CIAH. 2018).

#### Land Preparation

To create an exquisite tilth, the land is prepared by one deep ploughing and then two or three harrowings. For drainage and moisture conservation, proper leveling is crucial. Sowing is frequently done in pits or channels in dry areas to enhance soil moisture retention and seedling establishment (Singh and rai, 2006).

#### Sowing Time, Method, and Spacing

Kachri is seeded in February–March for summer cultivation and in June–July when the monsoon rains start. The technique of direct sowing involves planting seeds two to three centimeters deep. A seed rate of 2-3 kg per hectare is advised, with a distance of 1.5 to 2.0 meters between rows and 0.6 to 1.0 meters

between plants (Thamburaj and singh, 2013).

### Nutrient Management

Kachri reacts favorably to organic food. Soil structure and moisture retention are enhanced by applying 10–15 t ha<sup>-1</sup> of farmyard manure during field preparation. It is advised to apply 40–50 kg of nitrogen and 20–25 kg of phosphorus per acre when using chemical fertilizers, with the nitrogen being administered in split doses (Sharma and yadav, 2012).

### Irrigation and weed management

Even though kachri can withstand dryness, production is increased by moderate watering during crucial phases like blooming and fruit development. Waterlogging and excessive watering should be avoided as they raise the risk of grape diseases and root rot (FAO, 2017). Weed competition might affect early development stages. It just takes one or two hand weeding to keep the area weed-free. In dry regions, mulching using organic wastes aids in weed suppression and soil moisture conservation.

### Pest and Disease Management

Fruit flies, red pumpkin beetles, and aphids are the main insect pests in Kachri, and powdery mildew, downy mildew, and mosaic virus are prevalent illnesses. For long-term control, integrated pest management techniques including crop rotation, pheromone trapping, neem-based biopesticides, and field cleaning work well (Dhillon *et al.*, 2005).

### Harvesting and Yield

To guarantee higher quality, fruits are picked when they are tender, typically 8–12 days following fruit set. Harvesting takes place every two to three days. An average yield of 60–80 q ha<sup>-1</sup> of fresh fruits can be achieved with better management techniques (Kumar and singh, 2015).

### Post-Harvest Handling and Uses

While mature kachri fruits are sliced and sun-dried for long-term preservation and use as a flavoring ingredient, fresh fruits are eaten as vegetables. Kachri is a staple of traditional meals in desert regions and is high in minerals and dietary fiber (Singh and jain, 2014).

### Conclusion

Underutilized and climate-resilient, kachri has enormous potential to diversify desert vegetable production systems. In dryland areas, the use of improved cultivars and scientific production technologies can increase farmer income, productivity, and nutritional security.

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### 3. HORTICULTURE

## Organic Vegetable Production under Changing Climatic Conditions

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### Abstract

Vegetable production is negatively impacted by climate change because of rising temperatures, erratic rainfall, and increased pressure from pests and diseases. By boosting soil health, biodiversity, and soil water-holding capacity, organic vegetable cultivation provides a climate-resilient and sustainable method. Crop diversification, the use of organic inputs, and regionally adapted cultivars are some strategies that assist lower the risks associated with climate change. Organic vegetable cultivation is still a viable approach for sustainable agriculture and food security in the face of shifting climate circumstances, despite obstacles like reduced yields and certification requirements.

### Introduction

Vegetable production is seriously threatened by climate change because of rising temperatures, erratic rainfall, and a rise in the prevalence of pests and diseases. Vegetable productivity and quality are unstable due to their extreme sensitivity to environmental fluctuations. In this context, growing vegetables organically is becoming a viable and climate-resilient strategy (Meena Kumari *et al.*, 2018). By enhancing biodiversity, improving soil health, and increasing soil water-holding capacity, organic farming methods help crops resist climate pressures. Therefore, a practical approach to sustainable vegetable agriculture in the face of shifting environmental circumstances is organic vegetable farming (Venkatesan *et al.*, 2024).

### Components of Organic Farming (Bhattacharyya *et al.*, 2008):

1. **Green Manuring** (Meelu *et al.* 2007):
  - a. The crop other than main crop grown for the purpose of enriching the soil for organic matter is called green

manure crop.

- b. It is a practice of ancient origin- is defined as the use of un-decomposed green plant material, grown in situ or cut and brought it for incorporation to improve soil productivity
- c. Green manure crops can contribute 30 - 60 kg N/ha annually to the subsequent crop.
- d. Ex: Sesbania, Sunhemp, Dhainacha, Gliricidia, Pongamia and Neem etc.

### 2. Biofertilizers

- a. Biofertilizers is a substance which contains living microorganisms which are applied to seeds, plant surface and soil application.
- b. Promotes the plant growth by increasing the supply or availability of primary nutrients to the host plant.
- c. Biofertilizers for micro-nutrients. (*Bacillus sp.*)

### 3. Compost

- a. The process of biological recycling by which waste is converted into organic manure is known as "composting".
- b. In the process of composting, organic wastes are decomposed due to the activity of bacteria and fungi.
- c. Bacteria : *Bacillus sp.*, *Pseudomonas sp.*, *Xanthomonas sp.*, etc.
- d. Fungi : *Trichoderma sp.*, *Fusarium sp.*, etc.
- e. These micro-organisms oxidize organic compounds to CO<sub>2</sub>, NO<sub>2</sub> and N<sub>2</sub>O<sub>3</sub>.

### 4. Vermicompost

- a. Vermicompost technology involves the bioconversion of organic waste into vermicasts, vermiwash utilizing earthworms.
- b. Benefits (Ravimycin, 2016):
- c. To renew the depleted soil fertility

- d. To augment the available pool of nutrients nitrogen and phosphorus
- e. To conserve more water and maintain soil quality

### Climate Change and its Impact

It is the global phenomenon of climate transformation characterized by the changes in the usual climate of the planet (regarding temperature, precipitation, and wind) that are especially caused by human activities (Lindsey, 2020).



### Causes for Climate change

Due to anthropogenic activities like Industrialization, Deforestation, Automobiles etc.

Impact of Climate change:

- Fluctuations in temperature
- Increase in soil salinity
- Water logging
- High atmospheric CO<sub>2</sub> concentration and UV radiation

### Negative impact of Climate change on Crop production

- Crop failures
- Reduction of yields
- Reduction in quality
- Increasing pest and disease problems
- Unavailability of nutrient source to plants

### Climate change mitigation through organic farming (Woolf *et al.*, 2010).

Organic agriculture has ability to reduce

Greenhouse gases emissions and in enhancing carbon sequestration in soils.

Much of the carbon is fixed into a more stable form and efficiently stored by turning the organic substrates into compost, which can cut current world carbon emissions by up to 10%.

Because there is less nitrogen input, it reduces N<sub>2</sub>O emissions. Regardless of the kind of nitrogen input, it is generally believed that 1-2 percent of the nitrogen applied to farming systems is released as N<sub>2</sub>O.

Less CO<sub>2</sub> emissions through erosion (due to better soil structure and more plant cover).

Lower CO<sub>2</sub> emissions from farming system inputs (pesticides and fertilizers produced using fossil fuel).

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## 4. AGRICULTURAL ENTOMOLOGY

### Drone Technology for Pest Management in Agriculture

Dulera, Jyoti G.

## Introduction

Agriculture is changing rapidly with the use of modern technology. One of the useful technologies in modern farming is the drone. A drone is a small unmanned flying machine that can be controlled from the ground. Drones are now being used for crop monitoring, spraying, pest detection and disease management. Pests are one of the major problems in agriculture. Insect pests can damage leaves, stems, flowers, fruits, seeds and roots. If pests are not managed at the right time, they can reduce crop yield and quality. Traditional pest management often requires large amounts of labour, time and pesticides. Sometimes farmers spray the whole field even when pests are present only in a small area. This can increase the cost of cultivation and may cause unnecessary pesticide use. Drone technology can help farmers detect and manage pests more efficiently. Drones equipped with cameras and spraying systems can observe the crop from the air and apply pesticides to selected areas. Therefore, drone-based pest management is becoming an important part of **precision agriculture**.

## How Drones Help in Pest Management

Drones can help in pest management in several ways. The first important use is early detection of pests. A drone can fly over a large field and take photographs or videos of the crop. These images can show changes in plant colour, leaf damage, plant growth and crop condition. Areas affected by insects can then be

identified. Modern drones can carry different types of cameras. Normal cameras provide visible images, while special cameras such as multispectral and thermal cameras can provide additional information about crop health. Healthy and damaged plants may show different patterns in these images. With the help of image analysis and artificial intelligence, pest-affected areas can be identified more quickly. For example, if a part of a cotton field is affected by sucking pests or caterpillars, a drone can help identify the affected area. The farmer can then inspect that area and take suitable pest management measures.

## Drone-Based Pesticide Spraying

One of the most important applications of drones is pesticide spraying. Agricultural spraying drones are fitted with tanks, pumps, nozzles and batteries. The required pesticide solution is filled into the tank, and the drone sprays it over the crop while flying at a suitable height. Drone spraying can be useful when the crop is tall, the field is wet, or entering the field with farm machinery is difficult. It can also reduce direct contact between farmers and pesticides because the operator can control the drone from a safe distance. Another important advantage is that drones can provide more uniform spraying when they are properly calibrated. The spraying speed, height, nozzle type and spray volume should be selected according to the crop, pesticide and target pest.



Drone spraying in Agriculture

**Precision Pest Management**

Drone technology is especially useful in precision pest management. Precision pest management means applying control measures only where and when they are required. In conventional spraying, the entire field may be treated even if the pest is found only in some areas. With drone technology, pest-affected areas can first be identified and then treated. This can help reduce unnecessary pesticide application. For example, suppose a 5-hectare field has pest infestation in only one hectare. Instead of spraying the complete field, the farmer may use drone-based monitoring to identify the affected area and concentrate the management operation there. This can save pesticide, water, labour and time.

**Benefits of Drone Technology in Pest Management**

Drone technology provides several benefits to farmers.

1. **Early Detection of Pests:** Drones can regularly monitor large crop areas. Early detection allows farmers to take action before the pest population becomes severe.
2. **Saves Labour:** Manual spraying requires workers to carry spraying equipment throughout the field. Drone spraying can reduce the need for manual movement and make spraying easier.
3. **Saves Time:** A drone can cover a large area in a relatively short time. This is especially useful during pest outbreaks when timely management is important.
4. **Reduces Pesticide Waste:** Targeted spraying can reduce unnecessary pesticide application. This may decrease the cost of pest management and reduce pesticide residues in the environment.
5. **Reduces Farmer Exposure:** During conventional spraying, farmers may come into direct contact with pesticide spray. Drone spraying allows the operator to maintain a greater distance from the sprayed area.
6. **Useful in Difficult Fields:** Drones can be useful in muddy fields, tall crops, uneven land and areas where tractors or other machines cannot easily operate.
7. **Better Crop Monitoring:** Drones can collect photographs and other crop information

regularly. This helps farmers understand changes in crop health and pest infestation.

**Role of Artificial Intelligence**

The combination of drones and artificial intelligence (AI) can make pest management more effective. AI-based software can analyse images collected by drones and identify unusual changes in plants. For example, an AI system can be trained to identify symptoms caused by specific insect pests. It can compare healthy and damaged plants and prepare a pest infestation map. This information can help farmers decide where management is required. In the future, drones may be able to automatically identify pest-affected areas and create spraying maps. This will make pest management faster and more precise.

**Drone Technology and Integrated Pest Management**

Drone technology should not be considered as a replacement for all other pest management methods. It should be used as a part of Integrated Pest Management (IPM).

IPM includes cultural, mechanical, biological and chemical methods of pest management. Regular crop monitoring is an important part of IPM. Drones can make monitoring faster and more efficient. For example, a drone may detect an area with a high pest population. The farmer can then visit that area and identify the pest. Depending on the pest and its population, biological control, mechanical control or need-based pesticide application can be selected. Thus, drones can support the IPM approach by improving pest monitoring and helping farmers make better decisions.

**Limitations of Drone-Based Pest Management**

Although drones have many advantages, there are also some limitations. The initial cost of purchasing a good agricultural drone can be high. Farmers also need trained operators to fly and maintain the drone. Battery life is another important limitation. Most agricultural drones can operate only for a limited period before the battery needs charging or replacement. Weather conditions such as strong wind and heavy rain can also affect drone operation.

Correct pesticide selection and application are very important. The pesticide label, recommended dose, spray volume, nozzle, flying height and safety instructions must be followed. Drone spraying should be carried out according to applicable agricultural and aviation regulations. Drones also cannot replace field scouting completely. Images may show that a crop is under stress, but field inspection may still be required to identify the exact pest and decide the correct management method.

### Future Scope

The future of drone technology in agriculture is promising. Smaller and more efficient drones, better cameras, improved sensors and AI-based software will make pest detection easier. In the future, drones may be connected with mobile applications, GPS, weather information and farm management systems. Farmers could receive alerts when pest infestation is detected. Drones could then be used for targeted treatment. The use of drones may also become more important in large-scale farms, research experiments, seed production, orchards and difficult-to-access agricultural areas.

### Conclusion

Drone technology is an important development in modern agriculture. It can help in **early pest detection, crop monitoring and precise pesticide spraying**. By identifying pest-affected areas and applying treatment only when required, drones can help save time, labour, water and pesticides.

However, drones should be used carefully and as a part of Integrated Pest Management. Proper training, correct pesticide dose, suitable spraying conditions and compliance with regulations are essential. Overall, drone technology has good potential to make pest management **faster, safer, more precise and environmentally responsible**. With further development in sensors, artificial intelligence and precision agriculture, drones can become an important tool for sustainable crop protection.

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## 5. AGRICULTURE EXTENSION

### Role of Women in Panchayat Raj System

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### Introduction

In our country, Panchayati Raj is not a recent development. Its historical illustration dates back over a millennium. Its origins may be traced back to Ancient Indian Institutions, when communities were small republics run by Panchayats. It's not that women couldn't get involved in politics during this time; rather, a

patriarchal system prevented them from doing so.

It has been acknowledged that a key factor in determining women's standing in any community is their empowerment. In India, caste and gender-based inequality are the most pervasive types of inequality ingrained in traditional society. Numerous studies revealed

that women were the underprivileged gender in the nation's rural and urban areas. Article 14 gives equal rights and opportunities to men and women in the political, economic, and social domains, with a focus on women. The state may practice affirmative discrimination in favour of women under Article 15(3). However, India was ranked 95th in the Gender Empowerment Measure (GEM) and 105th in the Gender Related Development Index (GDI) in the Human Development Report (2001).

Half of India's population is made up of women from a variety of social, economic, political, geographical, and linguistic backgrounds. Although women are the cornerstones of the family, rural women actually portray a picture of object poverty and exploitation both within and outside the house. Women's roles have always been limited to domestic duties and farming. Although the women have a lot of potential for growth, they are unable to recognise their own strengths. Motivating people to engage in the political and socioeconomic actions necessary for their growth is all that is needed. If they are effectively mobilised and organised, they can become an invaluable resource in the development process. In 1995, Panchayati Raj Institutions implemented a 33.33 percent seat reservation for women due to the significance of women in shifting the political and socioeconomic landscape. However, the committee on the condition of women in India (1974) had to pay attention to the issue of women's participation in Panchayats in India. The National Perspective Plan for Women (1988) advocated for women in all rural local self-governing organisations at all levels, arguing that political power and access to decision-making authority are essential prerequisites. The 73<sup>rd</sup> constitutional amendment required women to be at least one-third of Panchayat members and chairpersons at all three levels—village, district, and intermediate. All the states without exception have adopted this reservation policy since then.

### Case Studies

Kumari and Singh (2015) studied the extent of role and performance of elected women Panchayat members in Panchayati Raj Institution. A total 75 women representatives were randomly selected from Pusa & Kalyanpur

Block of Samastipur district in Bihar. 40 villages were selected from the two selected blocks. The findings revealed that maximum member of elected women members of Gram Panchayats (78.64%) could perform only a little if their position was seen in totality and against the responsibilities. The association of role performance with interaction style, participation, empowerment, family education and family income were observed to be positive and highly significant at 1% level of probability. The partial regression coefficients are highly significant in case of interaction style and personal education. There was substantial direct effect of participation, family education, family income, house type, social linkage, marital status, family type and age.

The AC Nielson ORG-MARG study showed that about 87% of elected women representatives (EWRs) had contested only once and only 14% had been re-elected. It was found on further analysis that one of the foremost reasons for this was because of the practice of rotational reservation of seats. Granting EWRs at least 10 years of continued opportunity by extending the rotation term of reserved seats can help them negotiate their political space in a better manner.

Numerically, today India can actually claim that there are more EWRs in India than the rest of the world put together. According to the Ministry of Panchayati Raj's mid-term appraisal of the 'State of the Panchayats 2006-07', there are about 10 lakh women in our PRIs constituting about 37 % of all those elected. Also, there are about 80,000 female Pradhans. In a study by the Centre for Women's Development Studies 1999, it was revealed that 95% of women surveyed believed that they would not have been elected had it not been for the reservation.

### Constraints to Women's Political Empowerment

1. The cases of politically motivated violence against women is one of the major constraints.
2. Women belonging to disadvantaged sections face double oppression.
3. It is very common to find the mindset of cultural stereotyping which is unable to accept a woman exercising power in a 'male domain', especially those belonging

- to disadvantaged communities.
4. Acceptability of women as elected representatives is also an issue. Male members try to create hurdles in the smooth functioning of the Panchayat taking advantage of the woman's illiteracy or ignorance.
  5. It is also observed that the officials with whom the EWRs must work sometimes also acts as an impediment in their work.

### Summary and Conclusion

In Indian Constitution, there are provisions for equal rights for all citizens irrespective of their social and economic status. The performance of elected women members is not directly influenced substantially by caste or personal education or family size or family type or house type or even empowerment. In fact, the degree of participation plays the most vital role in performance by the elected women members in Gram Panchayat.

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## 6. SOIL SCIENCE

### Production of Urea-Free Coir-Pith Compost

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### Introduction

Coir pith is a by-product generated from coir industries. It consists of short fibres and mesocarp pith that remain after extracting long fibres from retted or fresh coconut husks. The fibre-to-pith ratio in the coconut mesocarp is

about 30:70 (w/w basis). In India, husks from nearly 40–60% of coconuts are utilized for coir fibre production. On average, 0.5 to 1 million tonnes of coir pith waste is generated annually in the country, which needs to be utilized effectively.

Coir pith has high porosity and a remarkable water-holding capacity of up to 500%, making it a unique soil amendment. Along with these beneficial physical properties, it also contains a high concentration of potash, enhancing its agricultural value. However, its high polyphenolic content makes raw coir pith toxic to the roots of many crops. Therefore, composting is considered the most suitable option for its beneficial use in agriculture, as the process reduces the concentration of toxic phenolics and makes plant nutrients more readily available.

### Composting of Coir-Pith

Composting coir pith is a challenge because it has a very high C:N ratio and lignin content ranging from 30 to 54%, which makes microbial decomposition difficult. To make it more amenable to microbial breakdown, the C:N ratio is reduced by adding urea, followed by the inoculation of lignocellulose-degrading mushroom fungi such as *Pleurotus sajor-caju*.

The compost produced through this technology becomes a good source of organic manure, improving soil physical properties, enriching the soil with valuable plant nutrients, and serving as a plant growth medium for both horticultural and field crops. However, the effectiveness of this technology depends on the regular availability of mushroom fungal culture, which often becomes a limiting factor for farmers.

### Urea-Free Composting of Coir-Pith

In this technology, organic materials with high nitrogen content and a low C:N ratio (such as animal manures) are mixed with organic materials with low nitrogen content and a high C:N ratio (such as coir pith). This balancing of high C:N and low C:N materials facilitates improved microbial decomposition of the substrates. The method is a low-cost, simple, and rapid composting technology that utilizes locally available resources, making it easily adoptable by both farmers and cottage-industry level entrepreneurs.

### Required Five Main Inputs

Coir-pith, Poultry manure, Lime (Calcium oxide), Rock phosphate and Water

### Steps for Coir-Pith Composting

#### 1. Site Selection

- a. Choose a shaded area protected from direct sunlight and rainfall.
- b. Alternatively, create shade using greenhouse nets draped on wooden poles.

#### 2. Preparation of Mixture

- a. Mix 90 kg coir pith + 10 kg poultry manure + 0.5 kg lime + 0.5 kg rock phosphate thoroughly.
- b. For larger heaps, mix 450 kg coir pith + 50 kg poultry manure + 2.5 kg lime + 2.5 kg rock phosphate and spread in a  $4 \times 2 \times 1$  m (L  $\times$  B  $\times$  H) area.

#### 3. Heap Formation

- a. Spread the mixture evenly in a pit or heap of  $2 \times 1 \times 0.5$  m dimensions (for small heap) or as per larger heap size.

#### 4. Moisture Management

- a. Sprinkle water regularly using a watering can to maintain uniform moisture throughout the heap.
- b. Avoid over-wetting or drying of the heap.

#### 5. Covering

- a. Cover the heap with gunny bags, greenhouse nets, or dry grasses to conserve moisture and protect from external exposure.

#### 6. Turning the Heap

- a. Turn the heap thoroughly once every 15 days.
- b. Turning helps aeration and speeds up decomposition.
- c. Progress is indicated by colour change from reddish-brown (raw) to dark brown.

#### 7. Completion of Composting

- a. Within 45–60 days, the coir pith turns dark brown to black, indicating full composting.

#### 8. Final Processing

- a. Shade dry the composted material.
- b. Pack and store the composted materials for future agricultural use

### Physico-Chemical and Microbial Properties of Urea-Free Coir Pith Compost

The coir-pith compost produced through this technology is a highly porous, dark-coloured, odour-free product with a pH ranging from 6.1 to 6.4 and a water-holding capacity of

up to 500%. The final compost has a C:N ratio of 21–22 and an organic carbon content of 28–30%.

Nutrient composition:

- Nitrogen (N): 1.3–1.4%
- Phosphorus (P): 0.9–1.2%
- Potassium (K): 1.3–1.6%

In addition, it is a good source of micronutrients such as iron (Fe), copper (Cu), zinc (Zn), and molybdenum (Mo). From a microbiological perspective, the urea-free coir-pith compost is enriched with beneficial microorganisms, including free-living nitrogen-fixing bacteria and phosphate-solubilizing bacteria. It also harbours significantly high populations of actinomycetes, which are known for their antibiotic production and play an important role in suppressing soil-borne pathogens.

#### Advantages of using coir-pith compost

- The urea-free coir-pith composting technology serves as an ideal input for

organic cultivation of both field and horticultural crops.

- Application of coir-pith compost improves soil physical properties and significantly enhances its water-holding capacity.
- It enriches soil organic matter and carbon content, making it particularly beneficial for soils with poor fertility.
- The compost supports better root development, thereby enhancing overall crop growth and yield.
- It provides an excellent medium for raising pot-tray seedlings, ensuring healthy and vigorous plant establishment.

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<https://cpcrri.gov.in>

## 7. AGRICULTURAL SCIENCES

### E-Agriculture 4.0: Integrating Artificial Intelligence, IoT, Digital Platforms, Remote Sensing and Smart Advisory Systems for Sustainable and Climate-Resilient Agriculture

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#### Abstract

Agriculture is undergoing a rapid digital transformation driven by information and communication technologies (ICT), artificial intelligence (AI), Internet of Things (IoT), cloud computing, remote sensing, mobile applications, digital platforms and data analytics. The concept of e-Agriculture has consequently expanded from the traditional use of computers and internet-based information services to an integrated digital ecosystem supporting production, marketing, finance, extension, supply chains and agricultural governance. Modern e-Agriculture enables farmers and other stakeholders to

access real-time information on weather, crop health, soil conditions, markets, finance and agricultural inputs, thereby improving decision-making and resource-use efficiency.

The integration of satellite imagery, unmanned aerial vehicles, IoT sensors and AI provides opportunities for precision crop monitoring, early detection of pests and diseases, irrigation management, yield forecasting and climate-risk assessment. Digital advisory platforms can deliver location-specific recommendations through smartphones, web applications, voice services and increasingly through AI-based conversational interfaces. Digital marketplaces and financial technologies can improve

farmers' access to markets, payments, credit and insurance. Recent research also emphasizes cloud-edge architectures and intelligent digital platforms capable of processing agricultural information closer to the point of use.

However, digital transformation is not automatically inclusive or sustainable. High initial costs, limited digital literacy, inadequate connectivity, fragmented data systems, cybersecurity risks, data ownership concerns and lack of interoperability remain important barriers, particularly for smallholder farmers. FAO evidence shows that digital and automated technologies can improve productivity, resilience and sustainability but that cost, digital skills and enabling infrastructure strongly influence adoption. This chapter discusses the evolution, components, applications, opportunities and challenges of e-Agriculture and examines its future role in building productive, inclusive, sustainable and climate-resilient agricultural systems.

**Keywords:** e-Agriculture; Digital Agriculture; Artificial Intelligence; Internet of Things; Digital Platforms; Remote Sensing; Smart Farming; Digital Advisory Services; Agricultural Informatics; Climate-Smart Agriculture

## 1. Introduction

Agriculture is increasingly becoming a knowledge- and information-intensive sector. Farmers must make decisions under conditions of uncertain rainfall, changing temperatures, pest and disease outbreaks, fluctuating input prices, changing market demand and increasing pressure on land and water resources. Conventional agricultural extension and information systems are often unable to provide timely, location-specific and continuously updated information to all farmers. e-Agriculture has emerged as an important approach for addressing these limitations by using digital technologies to improve access to information, services and decision support.

The Food and Agriculture Organization of the United Nations describes e-Agriculture as an area concerned with ICT applications in agriculture and rural development. Its current thematic framework encompasses advisory services, agribusiness, agricultural marketing,

value chains, AI, big data, cloud computing, digital technologies, climate-smart agriculture and digital financial services. Thus, e-Agriculture is no longer restricted to websites or electronic information dissemination; it represents a broad digital ecosystem connecting farmers with knowledge, technologies, markets, institutions and services.

The transformation from conventional ICT-based agriculture toward Digital Agriculture and e-Agriculture 4.0 has been accelerated by smartphones, affordable sensors, satellite data, cloud platforms and artificial intelligence. Digital technologies allow agricultural information to be collected, processed and delivered at unprecedented speed. In India, for example, digital agriculture initiatives have incorporated agricultural e-extension, fintech, remote sensing, precision agriculture, e-commerce, AI, drones and satellite imagery. FAO has identified these technologies as important components of India's emerging digital agricultural ecosystem.

One of the most visible applications of e-Agriculture is digital agricultural advisory services. Farmers can receive information through mobile applications, SMS, websites, call centres and social-media-based services. Such platforms can provide recommendations on crop selection, sowing dates, fertilizer application, pest management, irrigation and harvesting. A systematic review of digital agriculture services in low- and middle-income countries found that many services concentrate on digital advisory and extension, with reported benefits including changes in farming practices and increased knowledge.

Artificial intelligence is now adding a new dimension to these advisory systems. AI can analyse large datasets obtained from weather stations, satellites, sensors, farm records and market databases. Machine-learning models can identify patterns that may not be readily apparent through conventional analysis. Applications include crop-yield prediction, disease recognition, weather-risk assessment, crop classification, soil assessment and market forecasting.

The development of **generative and conversational AI** is particularly significant for e-Agriculture. Instead of requiring farmers

to navigate complex applications, AI systems can potentially allow farmers to ask questions in natural language or through voice interfaces. This is highly relevant to rural populations where literacy, language and technical skills may limit the use of conventional digital systems. Current developments in India also indicate increasing interest in AI-based agricultural advisory systems and voice-first interfaces designed for local users. Recent industry discussion highlights the integration of satellite imagery, GIS, agentic AI and voice-driven interfaces into India's agricultural value chain.

**Internet of Things (IoT)** is another major component of e-Agriculture. IoT-based soil-moisture sensors, weather stations, cameras and other field devices can continuously collect information. These data can be transferred to cloud or edge-computing platforms for analysis. Farmers can then receive alerts concerning irrigation requirements, abnormal temperature conditions, soil moisture and crop health. The combination of IoT and AI therefore allows e-Agriculture systems to move from information delivery toward automated monitoring and predictive decision support.

Remote sensing and geospatial technologies provide another essential information layer. Satellite imagery can monitor agricultural areas over large geographical regions, while UAVs can provide high-resolution information at the farm level. Vegetation indices and other remotely sensed indicators can be combined with field observations and weather data to assess crop growth, water stress and potential pest or disease problems. The resulting information can be integrated into digital platforms and converted into farmer-specific recommendations.

e-Agriculture also has an important role in agricultural marketing and value-chain development. Digital marketplaces can connect farmers with buyers, processors and consumers. Online platforms can provide information about commodity prices, demand and availability. Digital financial services can facilitate payments, credit, insurance and other financial products. FAO notes that digital technologies can improve the functioning of

food markets and facilitate smallholder farmers' integration into markets and value chains.

Another important application is digital climate-smart agriculture. Climate change creates increasing uncertainty concerning rainfall, temperature, droughts, floods and extreme weather events. Digital systems can integrate weather forecasts, satellite observations and crop information to provide early warnings and adaptation recommendations. Farmers can use these services to adjust sowing dates, select suitable crops or varieties, optimize irrigation and prepare contingency measures.

Despite these benefits, adoption of e-Agriculture remains uneven. A major challenge is the digital divide. Smallholder farmers may have limited access to smartphones, reliable internet connections, electricity and digital training. FAO's analysis of digitalization and automation in low- and middle-income countries identifies high investment costs, inadequate digital skills and insufficient enabling environments as major barriers to adoption.

Interoperability is another challenge. Agricultural information is often distributed across multiple organizations and platforms using different data formats. Effective e-Agriculture requires standards that allow weather, soil, crop, satellite, market and farmer data to communicate across systems. Data governance, privacy, cybersecurity and ownership must also be addressed. Farmers should understand how their data are collected, stored, shared and used.

Recent research also emphasizes the importance of scalability and sustainability. A 2024 review of agricultural digitalization found that digital technologies can improve production efficiency, resource management and sustainability, but high costs, reliability and scalability continue to limit widespread implementation. Therefore, future e-Agriculture systems should be designed to be affordable, interoperable, locally adaptable and usable by small as well as large farms.

For India and other developing agricultural economies, e-Agriculture offers an opportunity to connect farmers with agricultural universities, extension agencies, markets,

financial institutions and government services. The greatest potential lies not in adopting individual technologies but in creating an integrated ecosystem in which information flows efficiently among all agricultural stakeholders.

The future of e-Agriculture is therefore expected to move toward intelligent, connected and farmer-centric agricultural ecosystems. AI, IoT, remote sensing, cloud-edge computing, digital marketplaces, robotics and conversational systems will increasingly work together. However, technology should complement farmer knowledge rather than replace it. Local expertise, agricultural extension and farmer participation must remain central to technology design.

In conclusion, e-Agriculture 4.0 represents a transition from simple electronic information delivery to an integrated digital agricultural ecosystem. When appropriately designed and implemented, it can improve productivity, resource-use efficiency, market access, climate resilience and sustainability. The major challenge for the coming years will be ensuring that these benefits reach smallholder farmers in an affordable, inclusive, secure and locally relevant manner.

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intelligence, satellite/GIS data, agentic AI and voice-first interfaces.

## 8. AGRICULTURAL ENGINEERING – AGRICULTURAL METEOROLOGY / AGROMETEOROLOGY

### Internet of Things (IoT) in Weather Monitoring

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#### Introduction

The Internet of Things (IoT) has significantly transformed weather monitoring by enabling the continuous collection, transmission, storage and analysis of meteorological data. Traditional weather observation systems generally depend on expensive instruments installed at widely separated locations and often require manual observation and maintenance. IoT technology combines low-cost sensors, microcontrollers, wireless communication, cloud computing and data analytics to establish automated weather monitoring networks capable of providing near-real-time information.

IoT-based weather stations can measure temperature, relative humidity, atmospheric pressure, rainfall, wind speed and direction, solar radiation, soil moisture and air-quality parameters. The availability of dense and continuously updated observations is particularly valuable for agriculture, disaster management, environmental monitoring, aviation, marine operations and smart-city planning. Recent research also demonstrates the increasing integration of IoT with artificial intelligence (AI), machine learning (ML), edge computing and advanced sensor technologies for improved prediction and decision-making.

#### IoT Architecture for Weather Monitoring

An IoT weather monitoring system generally consists of four interconnected layers: sensing, processing, communication and application.

The sensing layer contains meteorological sensors that convert physical environmental conditions into electrical or digital signals.

Common measurements include temperature, humidity, pressure, rainfall, wind, solar radiation and soil moisture.

The processing layer consists of microcontrollers or single-board computers such as ESP32, ESP8266, Arduino and Raspberry Pi. These devices acquire sensor readings, perform calibration and filtering, manage power consumption and prepare data for transmission.

The communication layer transfers observations from the weather station to a remote server or cloud platform. Depending on the deployment environment, Wi-Fi, cellular networks, LoRa/LoRaWAN, Bluetooth, Zigbee and other wireless technologies can be used. Selection depends on range, bandwidth, power consumption, reliability and cost.

The application layer includes cloud databases, web dashboards, mobile applications and analytical platforms. Data can be visualized in real time, stored for historical analysis and used to generate alerts or automated responses. IoT architecture therefore converts raw sensor observations into accessible and actionable information.

#### Major Sensors and Parameters

Temperature and humidity are among the most frequently monitored parameters. Low-cost digital sensors such as DHT-series devices are suitable for basic applications, whereas professional meteorological systems require higher-accuracy temperature and humidity sensors.

Atmospheric pressure sensors such as BMP-series devices are useful for weather trend analysis, altitude estimation and identification of changing atmospheric conditions. Pressure changes can provide

useful information about approaching weather systems.

Rainfall can be measured using tipping-bucket, optical and weighing-type rain gauges. Tipping-bucket gauges are widely used in IoT stations because they provide quantitative rainfall measurements at relatively low cost. Optical and weighing gauges offer additional capabilities but generally involve higher cost and complexity.

Wind speed is commonly measured using cup anemometers, while wind direction is measured using wind vanes or rotary encoders. Ultrasonic anemometers provide wind speed and direction without moving components and therefore require relatively little mechanical maintenance.

Solar radiation is important for agricultural management, climate studies and solar-energy applications. Pyranometers provide accurate measurements, while photodiodes and other low-cost optical sensors can be used where moderate accuracy is acceptable.

In agricultural applications, soil-moisture and soil-temperature sensors complement atmospheric observations. Capacitive, resistive and time-domain reflectometry techniques are commonly used for soil-moisture measurement. Integration of soil and weather observations supports improved irrigation scheduling and crop management.

### **Embedded Platforms and Data Communication**

ESP32 and ESP8266 platforms are particularly useful for IoT weather stations because they combine processing capability, wireless connectivity and relatively low power consumption. ESP32 additionally provides Bluetooth/BLE and improved processing and power-management capabilities.

Arduino boards remain popular for educational and prototype systems because of their simple programming environment and extensive software support. Raspberry Pi systems are more appropriate when substantial local processing, data storage, machine-learning inference or camera integration is required. For remote stations, low-power microcontrollers combined with deep-sleep operation and solar power can significantly extend operational life.

For long-distance agricultural and rural deployments, LoRaWAN is particularly attractive because it supports low-power transmission over long distances. Cellular communication is useful where network coverage is available, while Wi-Fi is appropriate for locations with local internet infrastructure.

### **Cloud Computing and Data Management**

Cloud platforms enable remote storage, visualization and analysis of weather observations. Platforms such as ThingSpeak, Blynk and commercial cloud services can receive sensor data through communication protocols such as HTTP and MQTT. Historical observations can be used to identify trends, detect anomalies and develop predictive models.

For organizations requiring greater control over data, self-hosted systems using time-series databases, visualization software and MQTT brokers can be adopted. Combining local data storage with cloud backup can improve resilience during internet interruptions. Modern IoT systems increasingly use edge and fog computing so that data quality control and preliminary analysis can be performed close to the sensors, reducing communication requirements and latency.

### **Applications of IoT Weather Monitoring**

#### ***Agriculture and Precision Farming***

Agriculture is one of the most important applications of IoT-based weather monitoring. Real-time information on temperature, rainfall, humidity, wind, solar radiation and soil moisture supports irrigation scheduling, planting, harvesting, pest and disease management and protection against heat and frost.

Integration of weather and soil data can improve evapotranspiration estimation and irrigation decisions. IoT-based systems can also support site-specific management because weather conditions may differ considerably even within a single farm. Recent reviews emphasize that IoT, sensors, AI and data analytics are becoming important components of precision and climate-smart agriculture.

**Disaster Early Warning**

Dense IoT weather networks can contribute to early warning for floods, storms, landslides and heatwaves. Real-time rainfall, soil-moisture and water-level observations can provide inputs for hazard-detection models. Automated alerts can help authorities and communities respond more rapidly to developing hazards.

**Aviation and Marine Monitoring**

Weather information is essential for aviation safety and marine navigation. IoT weather stations can provide continuous measurements of wind, temperature, pressure, precipitation and visibility. Marine weather stations can improve observations in coastal and offshore areas where conventional monitoring networks may have limited coverage.

**Urban and Environmental Monitoring**

Cities experience localized variations in temperature, precipitation and air quality. Distributed IoT sensors can identify urban heat islands and pollution hotspots and provide information for urban planning and public-health interventions. Weather data can also be integrated with smart irrigation, stormwater management, building management and transportation systems.

**Challenges**

Despite its advantages, IoT weather monitoring faces several technical and operational challenges. Sensor accuracy, calibration, environmental exposure, data quality, power availability, communication reliability and cybersecurity are major concerns. Low-cost sensors may not provide the accuracy required for professional meteorological applications. Remote stations also require reliable power systems and protection against harsh weather conditions.

Data interoperability and standardization are important when information from different manufacturers and networks must be integrated. Security and privacy become increasingly important as large numbers of connected devices exchange environmental data. Recent studies identify implementation cost, infrastructure requirements, cybersecurity, interoperability and availability of skilled personnel as continuing barriers to

large-scale adoption.

**Future Trends**

The future of IoT weather monitoring is closely associated with AI, machine learning, edge computing, advanced sensors and high-speed communication networks. ML models can support anomaly detection, sensor-failure prediction, adaptive sampling and localized forecasting. LSTM and other deep-learning approaches can exploit temporal and spatial weather observations for predictive applications.

Advanced MEMS and spectroscopic sensors are expected to provide smaller, more sensitive and multifunctional monitoring devices. Integration with drones, autonomous vehicles and robots can create mobile weather-observation networks, particularly useful for precision agriculture.

5G and future communication technologies can support large numbers of connected devices, low-latency communication and edge computing. Blockchain-based approaches may improve data integrity and traceability, although their practical application in weather monitoring remains an emerging area.

**Conclusion**

IoT has transformed weather monitoring from relatively sparse and manually operated observation systems into automated, connected and data-intensive networks. The integration of sensors, embedded computing, wireless communication and cloud or edge platforms enables continuous monitoring and rapid access to environmental information. Agricultural applications are particularly promising because real-time weather and soil observations can improve irrigation, crop management and resource-use efficiency.

Future systems will increasingly combine IoT with AI, machine learning, advanced sensors, autonomous platforms and intelligent communication networks. However, successful deployment will require attention to sensor calibration, power management, communication reliability, cybersecurity, interoperability and cost. Overall, IoT-based weather monitoring represents an important technological foundation for precision agriculture, climate-resilient decision-making, environmental management and effective

early-warning systems.

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