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Impact of El Nino on Indian Agriculture

Chauhan Karmadip, Mote, B. M. And Sorathiya Tejeshkumar

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Introduction

A Climate Story That Begins Thousands of Kilometres Away

"El Niño is nature's reminder that a small change in the ocean can completely change life on land."

Every year, millions of Indian farmers eagerly await the arrival of the southwest monsoon. The monsoon is often called the lifeline of Indian agriculture because nearly half of the country's cultivated land still depends directly on rainfall. A timely and well-distributed monsoon supports crop growth, replenishes reservoirs, and sustains rural livelihoods.

Yet, the fate of India's monsoon is influenced not only by local weather conditions but also by events occurring thousands of kilometers away in the Pacific Ocean. One such phenomenon is El Niño, a natural climate event that has the power to alter rainfall patterns across the globe. Although it originates near the equator in the Pacific Ocean, its effects can reach Indian farms, influencing crop production, water availability, and food security.

In recent decades, as climate change intensifies weather extremes, understanding EL Niño has become more important than ever. Farmers, scientists, and policymakers are increasingly recognizing that events occurring far from India can significantly shape the future of Indian agriculture.

What is El Niño?

El Niño (Spanish for "Little Boy") is part of a broader climate cycle known as the EL Niño-Southern Oscillation (ENSO).

El Niño is a climate phenomenon characterized by the unusual warming of sea surface waters in the central and eastern tropical Pacific Ocean. Normally, trade winds push warm water toward the western Pacific near Indonesia and Australia. During an El Niño event, these winds weaken, allowing warm water to spread eastward across the Pacific.

These warming changes atmospheric circulation patterns, affect rainfall, temperature, and weather conditions in many parts of the world. Some regions receive excessive rainfall, while others experience drought conditions.

The Link between El Niño and the Indian Monsoon

The Indian monsoon is driven by temperature differences between land and ocean. During summer, the Indian subcontinent heats up faster than the surrounding oceans, creating a low-pressure area that draws moisture-laden winds from the Indian Ocean.

El Niño disrupts this delicate atmospheric balance. The warming of the Pacific Ocean alters global wind circulation and weakens the monsoon circulation over South Asia. As a result, India often experiences below-normal rainfall during El Niño years.

Historically, several major droughts in India have been associated with El Niño events. Although every El Niño does not automatically lead to drought, the probability of monsoon deficiency generally increases during such years.

Scientists estimate that many of India's severe monsoon failures during the twentieth and twenty-first centuries have coincided with strong El Niño episodes.

India's agriculture is closely linked to the monsoon. Although irrigation facilities have expanded over the years, millions of farmers still depend on seasonal rainfall for cultivating crops such as rice, maize, soybean, cotton, groundnut, pulses, and millets. The monsoon determines when farmers sow their fields, how much water is available in the soil, the recharge of groundwater, reservoir storage, and ultimately the country's food production. When the monsoon performs poorly, its effects are felt not only by farmers but also by consumers, industries, and the overall economy.

One of the major factors influencing the Indian monsoon is **El Niño**, a climate phenomenon that occurs when sea surface temperatures in the central and eastern Pacific Ocean become unusually warm. Although it develops thousands of kilometres away from India, EL Niño often weakens the southwest monsoon, resulting in below-normal rainfall across many parts of the country.

A delayed or weak monsoon caused by EL Niño can postpone sowing, shorten the crop-growing season, and sometimes force farmers to re-sow their fields after long dry spells. Reduced rainfall leads to poor seed germination, moisture stress, lower crop yields, and, in severe cases, crop failure. Rainfed regions in states such as Maharashtra, Karnataka, Gujarat, Rajasthan, and Telangana are especially vulnerable because they rely heavily on natural rainfall.

EL Niño also contributes to water scarcity by reducing reservoir levels, river flows, and groundwater recharge. At the same time, higher temperatures increase evaporation and crop water demand, exposing crops like wheat, rice, maize, cotton, and groundnut to heat stress during critical growth stages. Livestock production is also affected, as reduced fodder availability and water shortages lower milk production and impact animal health.

The effects of EL Niño are becoming even more complex due to climate change. Rising global temperatures have increased the frequency of extreme weather events, leading to unpredictable rainfall patterns. Today, India may experience prolonged dry spells followed by intense rainfall and flooding within the same monsoon season. For agriculture, the timing and distribution of rainfall are often more important than the total amount received making farming increasingly uncertain.

Building resilience against El Niño requires long-term adaptation strategies. Water conservation through farm ponds, rainwater harvesting, and efficient irrigation systems can improve water availability during dry periods. Growing drought-tolerant and short-duration crop varieties, diversifying crops, adopting conservation agriculture, and using accurate weather forecasts can help farmers reduce losses and improve productivity.

Conclusion

EL Niño is a major factor influencing India's agriculture, water resources, and food security. As climate change makes weather patterns increasingly unpredictable, farmers face greater challenges in managing crops and livelihoods. However, advances in weather forecasting, water conservation and climate-smart farming practices offer effective ways to reduce these risks. By understanding EL Niño and adopting resilient agricultural strategies, India can better protect its farming sector and ensure sustainable food production for future generations.

2. AGRICULTURE ENGINEERING

Revolutionizing Agriculture: Applications of Drone Technology in Modern Farming

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Introduction

Agriculture is the backbone of many economies and plays a crucial role in ensuring food security for a growing global population. However, traditional farming methods often face challenges such as labor shortages, inefficient resource utilization, pest infestations, and unpredictable climatic conditions. The rapid advancement of technology has introduced innovative solutions to these challenges, among which drone technology has emerged as a game-changing tool. Drones, also known as Unmanned Aerial Vehicles (UAVs), are transforming modern farming by enabling precision agriculture, improving productivity, reducing costs, and promoting sustainable agricultural practices.

Understanding Agricultural Drones

Agricultural drones are remotely controlled or autonomous flying devices equipped with cameras, sensors, GPS systems, and data-processing software. These technologies allow farmers to collect accurate information about crops, soil conditions, irrigation requirements, and overall farm health. By providing real-time insights, drones help farmers make informed decisions and optimize agricultural operations.

Applications of Drone Technology in Modern Farming

1. **Crop Monitoring and Surveillance:** One of the most significant applications of drones in agriculture is crop monitoring. Drones capture high-resolution aerial images that provide detailed information about crop growth and field conditions. Farmers can identify areas affected by diseases, pests, nutrient deficiencies, or water stress at an early stage, allowing timely corrective measures.
2. **Precision Agriculture:** Precision agriculture involves managing crops based on specific field conditions rather than treating the entire field uniformly. Drones collect detailed data that help farmers apply fertilizers, pesticides, and water precisely where needed. This targeted approach improves efficiency and reduces wastage.
3. **Soil and Field Analysis:** Before planting, drones can survey fields and generate three-dimensional maps of agricultural land. These maps provide information about soil quality, elevation, drainage patterns, and moisture levels. Such data assist farmers in selecting suitable crops and planning effective farming strategies.
4. **Irrigation Management:** Water is a valuable agricultural resource, and efficient irrigation is essential for crop productivity. Drones equipped with thermal sensors can detect areas experiencing water stress. Farmers can then adjust irrigation schedules to ensure optimal water distribution, reducing water consumption and enhancing crop health.
5. **Pesticide and Fertilizer Spraying:** Modern agricultural drones are capable of spraying pesticides, herbicides, and fertilizers with remarkable precision. Drone spraying reduces human exposure to harmful chemicals, minimizes environmental contamination, and ensures uniform application across fields. It also saves time and labor compared to conventional spraying methods.
6. **Crop Health Assessment:** Multispectral and infrared sensors mounted on drones can assess crop health by measuring plant reflectance. These sensors detect subtle changes in vegetation that may indicate disease or nutrient deficiencies. Early identification helps prevent large-scale crop damage and improves yields.
7. **Crop Yield Estimation:** Drones collect extensive field data that can be analyzed to predict crop yields accurately. Yield estimation helps farmers plan harvesting operations, storage facilities, transportation logistics, and marketing strategies more effectively.
8. **Livestock Monitoring:** In addition to crop farming, drones are useful in livestock management. They can monitor animal movement, locate missing animals, and assess grazing conditions over large areas. This reduces labor requirements and improves farm management efficiency.

Benefits of Drone Technology in Agriculture

Increased Productivity

Real-time monitoring and precise management practices lead to higher crop yields and improved farm performance.

Cost Reduction

Drone-based operations reduce labor costs, minimize input wastage, and improve resource utilization.

Time Efficiency

Large agricultural areas can be surveyed within a short period, enabling quick decision-making and timely interventions.

Environmental Sustainability

By reducing excessive use of fertilizers, pesticides, and water, drones contribute to environmentally friendly farming practices and help conserve natural resources.

Improved Decision-Making

Accurate data collected by drones allow farmers to make informed decisions regarding planting, irrigation, pest control, and harvesting.

Challenges of Drone Adoption

Despite their advantages, agricultural drones face several challenges:

- High initial investment and maintenance costs.
- Need for technical expertise and training.
- Regulatory restrictions governing drone operations.
- Limited battery life and flight duration.
- Data storage and privacy concerns.

Addressing these challenges through technological improvements and supportive government policies can encourage wider adoption.

Future Prospects

The future of drone technology in agriculture is highly promising. Integration with Artificial Intelligence (AI), Machine Learning (ML), Geographic Information Systems (GIS), and the Internet of Things (IoT) will further enhance drone capabilities. Autonomous drones capable of real-time analysis and decision-making are expected to revolutionize farming practices, making agriculture more productive, efficient, and sustainable.

How Drones Are Used on the Farm Today

The benefits of efficiency and precision are compelling, but how do they translate into daily tasks on the farm? Let's explore the most common and impactful agricultural drone uses that are actively transforming modern farming. These are the practical ways this smart farming technology gets its hands dirty, so to speak, helping you make smarter, faster decisions from planting to harvest.

One of the most powerful applications is crop monitoring with drones. Think of it as giving your fields a regular health check-up from the sky. Outfitted with specialized multispectral cameras, these drones see beyond the visible spectrum of light. They can measure chlorophyll levels, assess water stress, and even conduct plant counts and height analysis. This data creates detailed health maps of your entire farm, highlighting struggling areas in vibrant colors. You can spot a pest infestation, an irrigation leak, or a nutrient deficiency at its earliest stage, allowing you to intervene with precision and prevent widespread damage. It’s proactive farming, guided by data you can see and trust.

From monitoring, we move to action with precision agriculture drones. Once a problem area is identified, larger drones equipped with tanks can be deployed. These drones fly a pre-programmed route, applying fertilizer, pesticides, or herbicides with incredible accuracy, often within centimeters of their target. This targeted approach is a game-changer. Instead of blanketing an entire field, you’re treating only the specific plants that need it. This not only saves a huge amount of money on chemicals but also drastically reduces environmental impact, protecting beneficial insects, the surrounding soil, and local waterways from unnecessary exposure.

The innovation doesn't stop there. Emerging agricultural drone uses now include dispersing seeds in hard-to-reach terrain or even pollinating crops to boost yields. For those with herds, livestock management drones make monitoring and counting animals across vast pastures a simple, automated task, ensuring the herd is safe and accounted for without hours of manual labor. From planting to protection to oversight, farming and drones are creating a full-cycle system of intelligent agriculture that empowers you at every single step.

Conclusion

Drone technology is revolutionizing modern agriculture by providing innovative solutions for crop monitoring, precision farming, irrigation management, pest control, and yield estimation. Its ability to collect accurate data and optimize resource utilization has made it an indispensable tool for modern farmers. As technology continues to advance, drones will play an increasingly important role in ensuring sustainable agricultural development and global food security.

References

Food and Agriculture Organization (FAO). Digital Technologies in Agriculture and Rural Areas.

United States Department of Agriculture. *Precision Agriculture and UAV Applications*.

Zhang, C., & Kovacs, J. M. (2012). "The Application of Small Unmanned Aerial Systems for Precision Agriculture: A Review." *Precision Agriculture*, 13(6), 693–712.

Tsouros, D. C., Bibi, S., & Sarigiannidis, P. G. (2019). "A Review on UAV-Based Applications for Precision Agriculture." *Information*, 10(11), 349.

Hunt, E. R., et al. (2018). "Advances in Agricultural Remote Sensing with UAVs." *Remote Sensing*, 10(4), 1–20.

Institute of Electrical and Electronics Engineers. Research publications on UAVs and precision agriculture.

World Bank. Reports on agricultural technology and sustainable farming.

https://www.antigravity.tech/in/blog/Types-of-Drones/farming-and-drones-agriculture

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3. DAIRY FARMING

Dairy Farming: Systems, Productivity, and Sustainability

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Jodhupr

Abstract

A Branch of agriculture, dairy farming concentrates mainly on raising animals. Largely the animals like cows, buffalo and goats are included so far as dairy farming is concerned. Dairy farming, though in most of the parts of our country, is carried out in unorganized manner yet it nurtures animals for production of milk and milk based products like Ghee, Paneer, Curd, Cream and many more items. The production is done for commercial sale or for processing of the same for further supply in the market. It provides income, nutritional foods and sustainable resources like manure and biogas etc. to the farmers. Dairy farming supports the economies of the country.

The growing population of our country needs the nutritional food and protein. This need is fulfilled by the farmers who are engaged in dairy farming. We have seen a significant change in the way the dairy products are produced. Earlier the dairy farming used to be done manually and was purely a labour oriented tough task. But now, with new technology innovations, the machines and other automatic equipments are available which have resulted in increase of production to meet the increased demand of the products. The other factors like animal care, sustainability etc. too have developed to a great extent.

Introduction

Dairy farming is and has been an important aspect of agricultural system for the past thousands of years in our country where 70% of the population living in villages. Our economy is primarily agricultural economy. Since people are living in villages so live-stocks play a very important part in the social and economic life of these villagers. Live-stocks like cows, buffalos and goats provide high quality food which remains rich in protein. India is not only one of the top milk producers in the world but also it is largest consumer of milk and milk products. In 2024-2025 the milk production in the country was 247.87 million tonnes with a growth of approximately 3.58% over the previous year (Source Press Information Bureau). Inspite of the high production and consumption the major part of the sector is unorganized.

Milk and dairy products, as we know, are main sources of high-quality protein, calcium, and micronutrients for human populations. Diary production has increased with the improved atomization and breeding. According to global agricultural trends, dairy production has intensified through improved breeding, mechanization, and precision farming. This growth, however, has raised concerns related to environmental impact, and proper management of animals.

This article evaluates:

- Modern Dairy Farming/Production Systems
- Key Productivity Determinants
- Technological Advancements, and
- Environmental Impact and Sustainability.

Dairy Production Systems

Dairy farming or production systems do not remain same everywhere. It changes and varies due to so many factors like geography, climatic conditions, socio-economic circumstances, availability of land and other resources etc. The systems, therefore, range from small scale to large scale commercial productions. The important dairy production systems include rural small farmers, middle class farmers who do not have their lands etc. and whose set ups are mainly close to the city areas. In addition to this there is a production system at large scale where the farmers do have their own lands, they have mechanized and automated systems of milking. Since such farmers are rich and resourceful so now-a-days they use robotic and AI based technologies for improving dairy production.

The main dairy farming/ production systems therefore include:

- **Small Scale systems**: These kinds of systems are prevalent in developing areas or regions where the farmers have very small number of live-stocks (like 1 to 10 animals only). The animals graze on crop residue or on natural grass lands. The manures are used for the crop and therefore such systems are normally part of mix farming.
- **The other system is Peri-urban** i.e. the system where the farming is done on rural –urban border/boundary. This way the farmers remain close to the city area where the products could be sold easily. The animals are kept in shed, grazing with supplementary feeding is also one of the distinguish feature of this system.
- **Rural Dairy Farming** is another farming system where the farmers have adequate land where the animals roam for grazing. The systems allow high mobility and natural grazing to the animals.
- **Commercial Dairy Farming or Dairy Farming at large scale:** This system is suitable for farmers who have the capacity to invest huge money as capital. It is a high volume and capital intensive agricultural dairy farming. Under this system of farming the farmers use the advance technologies and automated systems for milking etc. The number of animals too remains more ranging from 150 to 1000 or even more than that number. This system is very expensive and small farmers cannot afford this. The number of animals remains more in view of the fact that automated system is very expensive and cost of production will be too high if number of animals is less. The viability of project will not be there if the dairy farm is not run with good number of animals.

Key Productivity Determinants:

In dairy farming the product yield is important and therefore the productivity needs to be monitored in such a way that the animals produce a good quantity and quality of the products. At the same time they remain healthy and in good climatic and decent housing conditions. It becomes the duty of the dairy farmers to take best care of the animals so that the yield efficiency remains at the top. The following important key productivity determinants are there which should be taken care of:

Genetics and Breeding

Genetic Improvement: has played a vital role in advancing dairy productivity and flock performance. Traditional methods such as selective breeding and artificial insemination enabled farmers to propagate desirable qualities across generations, leading to substantial gains in milk production and quality. More recently, genomic selection has enhanced this progress by allowing breeders to identify superior animals at an early age using DNA-based information and evidence.

The following key traits are targeted through genetic improvement:

- Higher milk production and increased fat and protein content;
- Better feed efficiency;
- Improved fertility and reproductive efficiency;
- Enhanced disease resistance.

Breeding: Modern research emphasizes balanced breeding goals. These programs increasingly recognize that selecting only for maximum milk yield can create unintended problems. These problems include poorer fertility, shorter productive life, and higher incidence of metabolic and health disorders. Thus, current research promotes balanced breeding goals that integrate productivity with animal health and welfare. Therefore, the important contemporary breeding goals are:

- Longevity and productive lifespan;
- Robustness and adaptability to environmental stress;
- Reduced susceptibility to metabolic diseases;

Nutrition and Feed Management

Nutritional diet for the animals is very important. In fact nutrition is a fundamental factor which affects milk production, reproductive performance, and overall health in dairy animals. It is therefore, needed that the farmers should take the best care of animals. The efficient nutritional management ensures that animals receive balanced amounts of energy, protein, minerals, vitamins, and water which are required for maintenance, growth, lactation, and reproduction. Current research in dairy nutrition emphasizes improving feed efficiency, enhancing rumen health, and maximizing nutrient utilization. These advances aim to increase productivity while reducing feed costs and environmental impacts.

Major developments in dairy nutrition include:

- **Precision feeding:** The farmers are using precision feeding instead of traditional feedings. They take care of nutrition requirement of each animal and accordingly the feed is prepared and given. Diets are formulated taking into consideration the age of animal, its body condition, stage of lactation, and production level etc. This helps to minimize nutrient wastage and improve efficiency.
- **Use of Feed additives:** Feed additives are non-nutritional ingredients and they are mixed into diets of live stocks. The use of feed additives is one of the major developments in dairy nutrition. Additives like probiotics, prebiotics, enzymes, yeast cultures, and rumen modifiers etc. improve digestion, stabilize rumen microbial activity, and enhance nutrient absorption.
- **Alternative feed resources:** The dairy farmers normally use the traditional feed for the animals but now they have started using other non-conventional feeds which has reduced dependence on expensive conventional grains and the cost of milk produced. The alternative feed also address the conventional fodder shortage.

Feed efficiency is also linked to reduced methane emissions, making it a key sustainability indicator. Overall, advances in dairy nutrition contribute not only to higher milk yield and better animal health but also to economic profitability and environmentally sustainable dairy production.

Animal Health and Welfare

The next important factor, in dairy farming, comes the health management. Milking an unhealthy animal will degrade the quality and its safety. Lower yield and severe economic and welfare problems will be there. So, animal health management is a critical component in dairy farming. If the animal is healthy then certainly it will produce more milk, reproduce efficiently, and will have longer productive lifespans.

The following are the major health challenges in dairy flocks:

- Mastitis: This affects udder health and milk quality;
- Lameness leads to pain. It reduces the mobility. The productivity is lowered;

- Reproductive disorders;
- Metabolic diseases.

It is said that prevention is better than cure and the modern research in animal health and welfare is doing exactly the same. The research emphasizes preventive rather than curative approaches. This preventive approach helps reduce treatment costs, improve productivity, and minimize reliance on antibiotics.

The preventive health strategies for animal health and welfare include improved housing systems, automated health monitoring and vaccination programmes.

- **Improved housing systems:** This includes better ventilation, good and comfortable flooring, bedding, and proper space allocation for the animals. These measures reduce stress and disease incidences among animals.
- **Automated health monitoring:** New and improved health checking devices are available and use of such devices like sensors, other wearable devices can detect early signs of illness through changes in activity, temperature, or milk composition etc. Thus, the health check- up and precautionary measures can be taken at an early stage of disease, if any.
- **Vaccination programs:** Time to time vaccination is very important and the recent research shows that such vaccination programs reduce the spread of infectious diseases within and between herds.

Animal welfare science has gained prominence, emphasizing behavioral indicators, stress reduction, and humane handling practices. Good animal welfare is now recognized not only as an ethical responsibility but also as a factor closely linked to productivity, product quality, and consumer acceptance. Therefore, integrating health management and welfare-centered practices is essential for the long-term sustainability of dairy farming.

Technological Innovations

Technology and innovations in dairy farming is often referred to as precision dairying. Use of Internet of things (IoT), use of AI, use of robotics etc. are all new development in technology field so far as dairy farming is concerned. Use of new technological development in dairy farming has optimized the milk yields, improvement of animal health and has reduced the resource waste and labour to a great and significant extent. Although the use of new and advanced technology has so many advantages yet the small farmers, and the farmers having less quantity of animals, cannot use the same since it is expensive one and will not be viable for small and medium farmers.

The following key innovations have changed the whole scenario of dairy farming:

1. Iot Sensors and Wearable which allow data collection and decision making, health and behaviour tracking of animals;
2. Robotic Milking allows lesser human intervention, proper monitoring of milking and milk yields ;
3. Precision nutrition and feeding to animals enable to keep track of proper health and milk yields;
4. AI use for data analysis. Since a huge data base can be collected with the use of AI tools so they allow farmers to analyse labour efficiency, detection of diseases at an early date and managing the farms in efficient and smooth manner. Obviously the huge data base allows further research in dairy farming.

Environmental Impact and Sustainability

Dairy farming, as we know, plays an important role in overall agriculture sector. However, it also has notable environmental issues. It contributes to greenhouse gas emissions. Dairy operations consume large quantities of water which is used for animal consumption, animal cleaning, and crop irrigation etc. Nutrient runoff is also another environmental issue in dairy farming as the same leads to water pollution and ecosystem disruption.

The researchers are working to address these environmental impacts of dairy farming. They are developing and testing various mitigation plans. These mitigation plans include manure management and dietary intervention to reduce emissions and runoff and to lower the amount of methane produced during digestion. The carbon sequestration is another important area of research in dairy farming. Another promising area of research involves increasing carbon sequestration through pasture management. Additionally, the use of life-cycle assessment (LCA) is also important aspect where the LCA in dairy farming evaluates the environment footprint of milking. The LCA allows for a comprehensive evaluation of the environmental impacts of dairy production, from feed cultivation to milk processing and distribution.

The primary objective of sustainable dairy farming is to maintain high levels of productivity to minimize environmental harm by ensuring that practices are socially acceptable. In order to achieve this- ongoing innovation, collaboration among stakeholders, and a commitment to continuous improvement in both environmental protection and animal welfare are necessary and important aspects.

Future Directions

In India the dairy farming is, to a significant level, in unorganized sector. However, in the recent past we have seen that large scale dairy farming in organized manner have come into existence. Therefore, it is needed that the research should be done in such a way that the dairy farming practices result in win-win position for both the sectors viz. organized and unorganized. The research should emphasize climate-smart practices, circular bio economy models, and integration of artificial intelligence. Although the adoption of automation is very expensive and difficult for small farmers yet the researchers should concentrate to develop such techniques which suit the farmers who are in unorganized sector and are working at very small level.

Conclusion

Dairy farming is a basis of India's agricultural economy which provides essential nutrition, sustainable livelihoods, and significant economic value. Although the dairy sector uses the traditional methods but we are now seeing that the sector has evolved from traditional, labour-intensive methods to sophisticated and technology-driven practices. New researches in genetics, nutrition, animal health, and automation have substantially improved the productivity. The advancements also ensured animal welfare. The constant research and innovation are addressing critical environmental and sustainability challenges too.

Inspite of remarkable advancement, the dairy farming faces persistent hurdles like:

- dominance of unorganized, small-scale operations;
- need for climate-smart, resource-efficient solutions;
- Bridging the gap between traditional and modern approaches;
- Non adoption of innovations and technological advancements.

To get rid of these hurdles dairy farming will need collaborative efforts. It would also require targeted research and supportive policies to ensure that technological advances give benefit to all the stakeholders, including small farmers.

Finally, the future of dairy farming in India depends on achieving a delicate balance: sustaining growth and productivity while protecting the environment, ensuring animal welfare, and meeting the nutritional needs of a growing population. Acceptance and implementation of innovation, fostering inclusivity, and prioritizing sustainability will be the key to building a strong and successful dairy sector for generations to come.

4. AGRICULTURAL ENTOMOLOGY

Gamma Radiation: An Important Tool for the Management of Storage Pests

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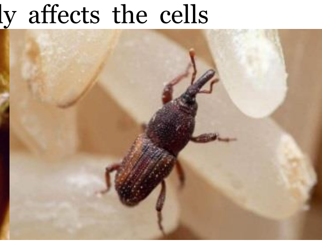
What is Gamma Radiation?

Gamma radiation is a type of high-energy radiation used for treating agricultural products. It is commonly produced from Cobalt-60 (Co-60). Gamma rays have good penetrating power and can pass through grains, packages and bulk stored products. Because of this, they can reach insects present inside or between grains where ordinary surface treatments may not work well. Gamma radiation can be used to reduce insect infestation without adding conventional pesticide residues to the grain. It can therefore be considered as a useful method for the protection of stored agricultural commodities.

How Does Gamma Radiation Control Storage Pests?

Gamma radiation mainly affects the cells and DNA of insects. It can damage important parts of the insect body and disturb normal growth and development. Young stages of insects are generally more sensitive to radiation than adults. Gamma radiation does not always kill insects immediately. At lower doses, it may stop the development of insects, reduce adult emergence and make insects unable to reproduce. Thus, even when insects are not killed immediately, their population can be reduced because they cannot produce healthy offspring. This is important in storage pest management because the main aim is not only to kill the insects present in the grain but also to stop the pest population from increasing.

Laser Grain Borer



Rice Weevil

Gamma Radiation Facility

Effect on Important Storage Pests

Different storage insects show different levels of sensitivity to gamma radiation. The required dose also depends on the insect species and its stage of development. Research has shown that gamma radiation can be effective against important pests of wheat and flour, including Rhyzopertha Dominica, Tribolium confusum, Lasioderma serricorne and Corcyra cephalonica. In one study, gamma radiation doses between 0.5 and 4 kGy were tested against stored-product insects. A dose of 2 kGy gave complete mortality of Rhyzopertha dominica after three days under the conditions of that study. Other insects required different doses or more time for complete control (Ahmed et al., 2011). Gamma radiation can also reduce egg laying, egg hatching and the production of new insects. Therefore, it can help to stop the pest population from increasing during storage.

Advantages of Gamma Radiation

Gamma radiation has several advantages for stored-grain pest management:

- **Non-chemical method:** It can reduce the need for chemical fumigants.
- **No conventional pesticide residue:** Gamma treatment does not add normal chemical pesticide residues to the commodity.
- **Good penetration:** Gamma rays can pass through bulk grains and packages.
- **Useful for stored grains:** It can be used for disinfestation of different agricultural commodities.
- **Reduces pest reproduction:** It can prevent insects from developing and producing new generations.
- **Useful for quarantine:** Irradiation can be considered for treatment of agricultural products before movement from one place to another.
- **Can be combined with other methods:** Gamma radiation can be used along with other non-chemical methods such as controlled

atmosphere, modified atmosphere and cold treatment.

Limitations

Although gamma radiation has good potential, it also has some limitations. An irradiation facility requires high initial investment, special equipment and trained workers. Therefore, the cost of treatment is an important factor for large-scale use. Another important point is that insects may not die immediately after treatment. Some insects may remain visible for some time even though their development or reproduction has been affected. Therefore, the correct radiation dose and proper evaluation after treatment are important. The effect of radiation on grain quality and seed germination should also be studied. This is especially important when the grain is going to be used as seed. Research on wheat showed that a 1 kGy gamma dose did not reduce germination under the tested conditions; however, the suitable dose may be different for different crops and purposes.

Future Scope

Gamma radiation has good potential as a modern method of storage pest management. Future research should focus on finding the best radiation dose for important storage pests such as *R. dominica*, *S. oryzae*, *T. castaneum* and *C. cephalonica*. Researchers should also study its effect on grain quality, germination, nutritional value and storage life. The method can also be combined with other storage practices such as proper grain drying, clean storage structures, hermetic storage, modified atmosphere and regular pest monitoring. Such an integrated approach may provide better protection of stored grains.

Conclusion

Gamma radiation is a promising non-chemical method for managing storage pests. It can kill insects, disturb their growth and reduce their reproduction. Its good penetration ability makes it useful for treating bulk grains and packaged agricultural products. It can also reduce dependence on conventional chemical fumigation. However, the correct radiation dose must be selected according to the insect species, developmental stage and type of grain. Grain quality, seed germination, treatment cost and safety requirements should also be considered. With further research and proper integration with other storage practices, gamma radiation can become a useful tool for safe, sustainable and effective storage pest management.

References

Ahmed, M., Hossain, M. M., Rahman, M. M. and Islam, M. S. (2011). Disinfestation of stored wheat grain and flour using gamma rays and microwave heating. Journal of Stored Products Research, 47(3): 191–196.

Follett, P. A., Akepsimaidis, G., Meneses, N., Murdoch, H. and Kotilainen, H. (2020). Advances in insect pest management in postharvest storage of cereals: Irradiation using machine sources for disinfestation. In: Maier, D. (Ed.), Advances in Postharvest Management of Cereals and Grains, pp. 319–338. Burleigh Dodds Science Publishing.

Hallman, G. J. (2013). Control of stored product pests by ionizing radiation. Journal of Stored Products Research, 52: 36–41.

Shanmugasundaram, S., Akbar, M. F., Thirupathi, V. et al. (2020). Disinfestation techniques for major cereals: A status report. Comprehensive Reviews in Food Science and Food Safety.

Srivastava, A. and Mishra, S. (2021). Ecofriendly nonchemical/nonthermal methods for disinfestation and control of pest/fungal infestation during storage of major important cereal grains: A review. Food Frontiers, 2: 136–150.

5. AGRICULTURE

Satellite Farming: Transforming Agriculture from Space to Field

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Abstract

Agriculture is entering a new era in which farmers can observe, analyse and manage their fields with information obtained from space. **Satellite farming**, also known as satellite-enabled precision agriculture, uses Earth-observation satellites, remote sensing, geographic information systems (GIS), artificial intelligence (AI), weather data and field observations to support better agricultural decisions. Satellite imagery can provide information on crop health, crop type, soil and moisture conditions, irrigation requirements, pest and disease stress, crop growth and potential yield. Modern satellite missions such as Sentinel-1 and Sentinel-2 provide frequent observations at useful spatial resolutions, while advances in artificial intelligence are making it possible to convert large volumes of satellite data into practical farm advisories.

The technology is particularly important for countries such as India, where farms are often small and fragmented and where farmers face increasing challenges from irregular rainfall, drought, floods, heat waves, soil degradation and rising input costs. Recent developments are moving satellite farming beyond simple crop monitoring towards field-level decision support, disease-risk mapping, yield prediction and automated agricultural management. The integration of satellite observations with drones, IoT sensors, weather stations and AI is expected to make agriculture more productive, resource-efficient and climate-resilient.

Keywords: Satellite farming, Remote sensing, Precision agriculture, Sentinel-1, Sentinel-2, NDVI, Artificial intelligence, Crop monitoring, Smart farming, GIS

Introduction

Agriculture has traditionally depended on farmers' experience, field observations and periodic visits to individual fields. Although these methods remain essential, they can become difficult when thousands or millions of hectares need to be monitored. A farmer may know that one part of a field is unhealthy, but identifying the exact location and cause of the problem at an early stage is often difficult.

This is where satellites provide a major advantage.

Satellites continuously observe the Earth's surface and collect information in different portions of the electromagnetic spectrum. Vegetation reflects and absorbs different wavelengths depending on its condition. Healthy vegetation, water-stressed crops, bare soil and damaged plants therefore produce different spectral signatures.

Satellite farming converts these observations into useful agricultural information. The basic concept is:

Satellite → Image → Processing → Crop information → Decision → Farm action

The Food and Agriculture Organization (FAO) already uses geospatial technologies for crop mapping, yield estimation, crop forecasting and agricultural monitoring over large areas. Satellite time-series data can also be used to identify crop phenology and seasonal changes.

Modern satellite farming is therefore not simply about looking at satellite photographs. It is about **using satellite-derived information to make better decisions at the farm level**.

What is Satellite Farming?

Satellite farming is an agricultural management approach in which satellite-based Earth observation data are combined with GIS, remote sensing, meteorological information, artificial intelligence and field observations to monitor and manage agricultural land.

A satellite image can provide information about:

- Crop growth and vigour
- Crop type and cultivated area
- Vegetation stress
- Water availability
- Irrigation performance
- Soil moisture
- Flood and drought impacts
- Pest and disease risk
- Crop phenology
- Biomass development
- Potential yield
- Harvest conditions

The major advantage is **spatial coverage**. A single satellite system can observe agricultural areas covering hundreds or thousands of square kilometres.

For example, the Copernicus Sentinel-2 mission provides multispectral observations with 13 spectral bands and a 290-km swath. The Sentinel-2 constellation provides frequent coverage, making it particularly valuable for agricultural monitoring.

How Does Satellite Farming Work?

The satellite farming system generally involves five major stages.

Satellite Data Acquisition

Earth-observation satellites collect information about agricultural fields. Important sources include optical and radar satellites.

Optical satellites measure reflected sunlight in visible, near-infrared and shortwave-infrared wavelengths.

Radar satellites, such as Sentinel-1, can observe the Earth's surface using microwave signals and have the important advantage of being capable of acquiring information through cloud cover and during night-time.

Image Processing

Raw satellite data must be processed before agricultural interpretation. Processing may include:

- Atmospheric correction
- Cloud masking
- Geometric correction
- Image mosaicking
- Temporal compositing
- Field boundary identification

Vegetation and Agricultural Indices

Satellite bands can be mathematically combined to generate indices.

One of the most widely used is the Normalized Difference Vegetation Index (NDVI):

$$NDVI=NIR-Red/\ NIR+Red$$

where **NIR** represents near-infrared reflectance and **Red** represents red-band reflectance.

Generally, vigorous green vegetation produces higher NDVI values, whereas bare soil, water or stressed vegetation produces lower values.

Other indices such as EVI, SAVI, NDWI and NDRE can provide additional information about vegetation, water and crop condition.

Artificial Intelligence and Machine Learning

The latest development is the integration of satellite data with AI and machine learning.

Algorithms such as Random Forest, Support Vector Machines, neural networks and deep-learning models can identify crop types, detect anomalies, estimate yield and classify field conditions.

Recent research has increasingly moved towards combining Sentinel-2 imagery with machine learning and process-based crop models for field-level yield estimation.

Agricultural Decision-Making

The final objective is not the satellite image itself but the decision derived from the information.

For example:

Satellite observation → Low vegetation index → Possible crop stress → Field verification → Irrigation/fertilizer/pest-management decision

This makes satellite farming a decision-support technology rather than merely an imaging technology.

Major Applications of Satellite Farming

Crop Health Monitoring

One of the most important applications is monitoring crop health throughout the growing season.

Repeated satellite observations allow farmers and agricultural experts to compare crop conditions over time. A sudden decline in vegetation indices may indicate:

- Water stress
- Nutrient deficiency
- Pest attack
- Disease
- Flooding
- Physical crop damage

Instead of inspecting the entire farm, field staff can concentrate on locations showing unusual changes.

Crop Identification and Acreage Estimation

Satellite imagery can identify different crops based on their spectral and temporal characteristics.

Crop mapping is useful for:

- Agricultural planning
- Procurement
- Food-security assessment
- Crop insurance
- Government programmes
- Market forecasting

FAO uses satellite and geospatial information for crop mapping and production estimation, demonstrating the potential of satellite technology for large-scale agricultural monitoring.

Irrigation and Water Management

Water is one of the most valuable agricultural resources. Satellite observations can help identify areas experiencing water stress and support irrigation planning.

Satellite-derived vegetation and moisture information can be combined with weather observations and field sensors to determine where irrigation attention is required.

This creates the possibility of moving from:

Irrigate the whole field → Irrigate according to crop need.

Such approaches can reduce unnecessary water use and improve water-use efficiency.

Drought Monitoring

Drought can affect large agricultural regions, but its effects may vary considerably from one field to another.

Satellite time-series data can identify changes in vegetation condition and provide information about drought impacts. When combined with rainfall, soil moisture and temperature data, satellite observations can contribute to agricultural drought early-warning systems.

Flood and Excess-Water Assessment

Flooding can cause serious damage to standing crops.

Radar satellites are particularly useful because radar observations can be acquired even when clouds are present. This makes satellite-based monitoring valuable during monsoon flooding, when optical imagery may be unavailable because of persistent cloud cover.

Pest and Disease Monitoring

Disease and pest attacks can create spatial patterns of crop stress.

A major emerging area is the combination of satellite imagery, field observations, weather information and AI for disease-risk prediction.

For example, ESA's current CROPWATCH project is developing satellite-based pathogen-risk mapping by combining Sentinel-2 imagery, field and laboratory observations, local weather and machine-learning models.

This represents an important shift from detecting damage after it occurs to predicting disease risk before major losses occur.

Crop Yield Estimation

Yield estimation before harvest is extremely important for farmers, governments, traders and food-processing industries.

Satellite observations can be combined with:

- Crop growth models
- Weather data
- Historical yields
- Soil information
- Vegetation indices
- Machine learning

Recent reviews indicate a growing movement towards field-level crop-yield estimation using Sentinel-2, machine learning, deep learning and data fusion with Sentinel-1 radar observations.

Satellite Farming and Indian Agriculture

India presents both a major challenge and a major opportunity for satellite farming.

Indian agriculture is characterised by diverse climates, multiple cropping systems, fragmented landholdings and strong dependence on monsoon rainfall. Farmers may experience drought in one region and flooding in another during the same season.

Satellite technology can support Indian agriculture through:

- Crop acreage estimation
- Crop condition monitoring
- Drought assessment
- Flood damage assessment
- Irrigation planning
- Crop insurance
- Soil and land-resource monitoring
- Yield forecasting

- Agricultural planning

India's growing space and geospatial ecosystem is also creating new opportunities for agricultural applications. In January 2025, India's Pixxel launched three hyperspectral satellites, marking an important development in the country's private Earth-observation sector. Hyperspectral observations have significant potential for detailed agricultural and environmental monitoring.

At the state level, satellite, GIS, UAV and AI technologies are also increasingly being integrated into agricultural management systems. Recent developments in Haryana, for example, demonstrate the potential for large-scale geo-enabled agricultural services involving crop monitoring, yield assessment, water management and crop insurance.

From Satellite Images to Smart Farms

The future of satellite farming lies in **data integration**.

A satellite alone cannot tell a farmer exactly why a crop is stressed. A better system combines multiple sources:

Satellite + Drone + IoT + Weather + Soil + AI + Farmer Knowledge

For example, satellites can identify a stressed portion of a field. A drone can then provide high-resolution imagery of that specific area. A soil sensor can measure soil moisture, while a weather station provides rainfall and temperature information. AI can combine these observations and generate an advisory.

Recent research has demonstrated the potential of combining satellite and UAV observations to improve biomass and nitrogen estimation while reducing the need for repeated drone surveys.

This integrated approach could become the foundation of **next-generation precision agriculture**.

Advantages of Satellite Farming

Satellite farming offers several important advantages.

- Wide-area monitoring: Large agricultural regions can be monitored without physically visiting every field.
- Frequent observations: Repeated satellite observations allow changes to be tracked during the crop season.
- Early detection: Crop stress may be identified before symptoms become obvious to the human eye.
- Resource conservation: Satellite-derived information can support more efficient use of water, fertilizer and pesticides.
- Cost effectiveness: Many satellite datasets, particularly from programmes such as Copernicus, are freely accessible.
- Historical analysis: Satellite archives allow researchers to study changes in agricultural land and crop conditions over many years.
- Climate resilience: Satellite monitoring can support responses to droughts, floods, heat waves and other climate-related hazards.

Challenges and Limitations

Despite its enormous potential, satellite farming has limitations.

- Cloud cover: Optical satellite imagery cannot always provide usable images during cloudy periods. Integration with radar data such as Sentinel-1 can reduce this problem. Recent AI research has demonstrated the value of combining Sentinel-1 and Sentinel-2 data for near-real-time crop monitoring under cloud-affected conditions.
- Spatial resolution: Satellite pixels may contain more than one crop or land-cover type, particularly in very small and fragmented farms.
- Need for ground truth: Satellite observations must be validated with field measurements. Without reliable ground data, AI models may produce misleading results.
- Technical knowledge: Processing satellite data requires knowledge of remote sensing, GIS, statistics and agriculture.
- Connectivity and digital literacy: Smallholder farmers may not have reliable internet access or may find complicated GIS dashboards difficult to use.

- Interpretation problem: A satellite can detect crop stress, but identifying whether the stress is caused by water, nutrient deficiency, disease or another factor often requires additional field information.

Therefore, satellite technology should support farmers and agricultural experts rather than replace field-level knowledge.

Future of Satellite Farming

The future of satellite farming is moving towards real-time, AI-assisted and farmer-friendly agricultural intelligence.

Several developments are particularly promising.

AI-powered crop monitoring

AI will increasingly analyse satellite time-series data automatically and identify abnormal crop behaviour.

Hyperspectral agriculture

Hyperspectral satellites can observe hundreds of narrow spectral bands. This may improve the detection of crop stress, nutrients, diseases and biochemical characteristics.

Satellite–drone integration

Satellites can identify where detailed drone observations are needed, reducing the cost of extensive UAV surveys.

Digital agricultural twins

Future systems may create digital representations of individual fields that combine satellite observations, soil properties, weather, crop models and farm-management records.

Automated advisories

Instead of showing farmers complex NDVI maps, future platforms may provide simple messages such as:

“Field 3 is showing increasing water stress. Check irrigation within the next 24–48 hours.”

This transition from **data to actionable advice** will be one of the most important developments in satellite farming.

A recent global development illustrates how rapidly the field is progressing: a 2026 study reported the first global agricultural field-boundary dataset at 10-metre resolution, covering 241 countries and territories and billions of remotely sensed field polygons. Such datasets could provide a consistent field-level foundation for global agricultural monitoring.

Conclusion

Satellite farming is transforming agriculture from a predominantly field-observation-based activity into a **data-driven and spatially intelligent system**. Satellites can provide repeated information about crop growth, water stress, land use, crop type, floods, droughts and potential yield across large areas. When satellite observations are combined with GIS, weather information, IoT sensors, drones and artificial intelligence, they can provide farmers and agricultural agencies with increasingly precise decision-support information.

The greatest opportunity is not simply to collect more satellite images, but to convert those images into **timely, affordable and understandable recommendations for farmers**. For India, where agriculture faces fragmented holdings, climatic uncertainty and pressure to increase productivity while conserving resources, satellite farming can become an important component of climate-smart and precision agriculture.

The future farm may therefore not be monitored only by the farmer standing in the field. It may also be monitored **from hundreds of kilometres above Earth**, with satellites continuously observing changes and intelligent systems helping farmers decide when, where and how to act.

Satellite farming is ultimately not about replacing the farmer—it is about giving the farmer a better view of the field.

References

FAO. (2026). Land Cover and Crop Monitoring: Geospatial Information for Sustainable Food Systems. Food and Agriculture Organization of the United Nations.

European Space Agency (ESA). (2026). Introducing Sentinel-2. Copernicus Sentinel-2 Earth Observation Mission.

European Space Agency (ESA). (2026). AI for Near Real-Time Crop Monitoring—A New Method. ESA Science Hub, November 2025.

European Space Agency (ESA). (2026). CROPWATCH: Satellite-Based Crop Pathogen Monitoring. ESA Space Solutions.

European Space Agency (ESA). (2026).

Food & Agriculture: Earth Observation and Digital Agriculture Projects. ESA Space Solutions.

Narimani, M., Pourreza, A., Moghimi, A., & Farajpoor, P. (2026). Sentinel-2 for Crop Yield Estimation: A Systematic Review. arXiv preprint.

Robinson, C., Muhawenayo, G., Khanal, S., et al. (2026). The First Global Agricultural Field Boundary Map at 10 m Resolution. arXiv preprint.

Rufin, P., Hammer, P. L., Thomas, L.-F., Lisboa, S. N., Ribeiro, N., Sitoe, A., Hostert, P., & Meyfroidt, P. (2025). National Level Satellite-Based Crop Field Inventories in Smallholder Landscapes. arXiv preprint.

Masrur, A., Olsen, P. A., Adler, P. R., Jackson, C., Myers, M. W., Sedghi, N., & Weil, R. R. (2025). Learning to See More: UAS-Guided Super-Resolution of Satellite Imagery for Precision Agriculture. arXiv preprint.

Kalogeras, A., Bormpoudakis, D., Tsardanidis, I., Loka, D. A., & Kontoes, C. (2025). Monitoring Digestate Application on Agricultural Crops Using Sentinel-2 Satellite Imagery. arXiv preprint.

European Space Agency (ESA). (2024). Satellite Technology Revolutionising European Agriculture. ESA Space Solutions.

Reuters. (2025). Google-backed Pixxel Successfully Launches India's First Private Satellite Constellation. Reuters, 14 January 2025.

6. HORTICULTURE

Plant Defense Priming and Induced Resistance in Vegetables

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Abstract

Plant defense priming and induced resistance represent eco-friendly strategies for enhancing crop protection by activating plants' innate immune systems. These methods, in contrast to direct chemical management, enable plants to react to biotic challenges like insect pests and diseases more quickly and efficiently. Beneficial microorganisms, plant extracts, and chemical elicitors are examples of priming agents that activate systemic acquired resistance (SAR) and induced systemic resistance (ISR) in vegetable crops, reducing disease incidence and insect damage. Defense priming increases resistance and promotes sustained vegetable production without incurring substantial metabolic expenses. The processes, agents, uses, advantages, difficulties, and potential future developments of plant defense priming and induced resistance in vegetable crops are reviewed in this article.

Keywords: Defense priming, induced resistance, SAR, ISR, vegetable crops, sustainable plant protection

Introduction

Fungal, bacterial, viral, and insect pests are just a few of the many biotic stresses that vegetable crops are regularly subjected to. The use of chemical pesticides has raised concerns about environmental contamination, health risks to humans, and the development of pest resistance. Alternatively, plants' innate immune systems can be stimulated to increase resistance against biotic stresses; plant defense priming and induced resistance offer promising, environmentally safe strategies to improve crop protection while reducing chemical inputs (Conrath *et al.,* 2015).

Concept of Plant Defense Priming

When plants are in a physiological condition known as "defense priming," they are more able to trigger defensive mechanisms when they are subsequently exposed to stress. Compared to non-primed plants, primed plants react to attacks more quickly and forcefully, frequently without constant defensive activation. This "memory" enables plants to effectively balance defense and development (Conrath, 2009).

Types of Induced Resistance

3.1 Systemic Acquired Resistance (SAR)

SAR provides long-lasting, broad-spectrum resistance across the plant and is initiated by localized infection. It is linked to the build-up of pathogenesis-related (PR) proteins and is mainly driven by salicylic acid (SA) signaling (Vallad and Goodman, 2004).

3.2 Induced Systemic Resistance (ISR)

Beneficial microbes like Bacillus species and Pseudomonas activate ISR. In contrast to SAR, ISR is primarily controlled by ethylene and jasmonic acid (JA) signaling pathways and does not include PR protein buildup. ISR works very well against necrotrophic infections and insect pests (Pieterse *et al.,* 2014).

Mechanisms of Defense Priming

Molecular, metabolic, and epigenetic modifications are all part of defense priming. When exposed to stress, primed plants exhibit stronger cell walls, increased accumulation of secondary metabolites, and quicker activation of defense genes. Defense memory is maintained by epigenetic changes such DNA methylation and histone alterations (Hilker *et al.,* 2016).

Priming Agents Used in Vegetable Crops

5.1 Chemical Elicitors

It is common practice to employ substances like salicylic acid, jasmonic acid, β-aminobutyric acid (BABA), and benzothiadiazole (BTH) to make crops resistant to pests and diseases (Walters *et al.,* 2013).

5.2 Biological Agents

Plant growth-promoting rhizobacteria (PGPR), mycorrhizal fungi, and endophytic microorganisms cause ISR and boost plant defense capability. Additionally, these biological agents enhance plant growth and nutrient absorption (Pieterse *et al.,* 2014).

5.3 Botanical Extracts and Natural Compounds

Neem extracts, chitosan, and seaweed extracts are examples of plant-derived substances that function as natural elicitors to trigger defensive reactions in vegetable crops (Iriti and Faoro, 2009).

Applications in Vegetable Crops

Vegetables including tomatoes, chillies, cucumbers, cabbage, and onions have all benefited from defense priming. For example, salicylic acid therapy lessens the severity of bacterial wilt and early blight in tomatoes, whereas PGPR-induced ISR lowers insect pests in cucurbits (Walters *et al.,* 2013).

Advantages of Defense Priming and Induced Resistance

- Reduced dependence on chemical pesticides
- Broad-spectrum and long-lasting resistance
- Minimal environmental impact
- Compatibility with IPM and organic farming
- Improved plant vigor and stress tolerance

These advantages make defense priming a valuable component of sustainable vegetable production systems (Conrath *et al*., 2015).

Limitations and Challenges

Despite its promise, defensive priming has drawbacks, including varying responses across crops and habitats, variable field performance, and a lack of commercial priming solutions. Effective implementation requires an understanding of crop-specific responses (Walters *et al.,* 2013).

Future Prospects and Research Needs

Future studies should concentrate on finding new priming agents, comprehending defensive memory's epigenetic regulation, and combining priming techniques with IPM and precision farming. The efficacy of induced resistance in vegetables will be further improved by developments in molecular biology and biotechnology (Hilker *et al.,* 2016).

Conclusion

In vegetable crops, plant defense priming and induced resistance provide viable, long-term substitutes for traditional pest and disease management. These techniques lower chemical inputs and support ecologically friendly vegetable production by boosting plants' natural resilience. Achieving long-term agricultural sustainability will need their incorporation into IPM frameworks.

References

Conrath, U. (2009). Priming of induced plant defense responses. *Advances in Botanical Research, 51*, 361–395.

Conrath, U., Beckers, G. J. M., Langenbach, C. J. G., and Jaskiewicz, M. R. (2015). Priming for enhanced defense. *Annual Review of Phytopathology, 53*, 97–119.

Hilker, M., Schwachtje, J., Baier, M., Balazadeh, S., Bäurle, I., Geiselhardt, S., and Kopka, J. (2016). Priming and memory of stress responses in organisms lacking a nervous system. *Biological Reviews, 91*(4), 1111–1133.

Iriti, M., and Faoro, F. (2009). Chemical diversity and defence metabolism: How plants cope with pathogens and pests. *International Journal of Molecular Sciences, 10*(8), 3371–3399.

Pieterse, C. M. J., Zamioudis, C., Berendsen, R. L., Weller, D. M., Van Wees, S. C. M., and Bakker, P. A. H. M. (2014). Induced systemic resistance by beneficial microbes. *Annual Review of Phytopathology, 52*, 347–375.

Vallad, G. E., and Goodman, R. M. (2004). Systemic acquired resistance and induced systemic resistance in conventional agriculture. *Crop Science, 44*(6), 1920–1934.

Walters, D. R., Ratsep, J., and Havis, N. D. (2013). Controlling crop diseases using induced resistance: Challenges for the future. *Journal of Experimental Botany, 64*(5), 1263–1280.

7. HORTICULTURE

Use of LED Lighting for Off-Season Vegetable Growth

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Introduction

Rapid urbanization, shifting weather patterns, and growing consumer demand for fresh food all year round have made off-season vegetable farming more crucial. Year-round output is limited by traditional open-field cultivation's strong reliance on seasonal fluctuations and sunshine availability (Kozai *et al.,* 2019). In this regard controlled environment agriculture (CEA), which permits the production of vegetables under controlled light, humidity, and temperature conditions has become a viable substitute. LED (Light Emitting Diode) lighting is one of the many technological inputs that have drawn a lot of attention due to its ability to assist off-season vegetable growth with more accuracy and efficiency (Morrow, 2008).

Importance of Light in Vegetable Growth

In vegetable crops, photosynthesis, plant shape, blooming, and yield are all significantly impacted by light. Plants use sunlight as their main energy source in the natural world, however during the winter or overcast seasons, light intensity and duration frequently become limiting. Poor growth, delayed flowering, and decreased yield are the outcomes of inadequate light. By supplying steady, sufficient light, artificial lighting systems make up for these drawbacks and enable off-season vegetable farming (Taiz *et al.,* 2015).

Concept of LED Lighting Technology

Semiconductor devices that generate light when an electric current flows through them are the foundation of LED lighting technology. LEDs use a lot less energy and generate less heat than conventional incandescent or fluorescent lighting. The ability of LEDs to generate light in particular wavelengths, such red, blue, and far-red, which are closely linked to photosynthetic activity and plant developmental processes, is one of its biggest advantages. Because of their spectrum controllability, LEDs are especially well-suited for regulated vegetable cultivation (Singh *et al.,* 2015).

Role of light Spectrum in off-Season Vegetable Production

Different light wavelengths have different effects on the growth and development of plants. Red light increases photosynthesis, blooming, and fruit production, whereas blue light encourages vegetative growth, leaf expansion, and chlorophyll synthesis. Plant height and blooming responses are influenced by far-red light. LED lighting systems may be tailored for certain vegetable crops and growth phases by varying the ratio of various wavelengths, guaranteeing maximum productivity at off-season times (Hogewoning *et al.,* 2010).

LED Lighting in Controlled Environment Agriculture

Vertical farming systems, plant factories, and greenhouses all make extensive use of LED illumination. While LEDs fully replace sunlight in indoor agricultural systems, they serve as additional lighting in greenhouses during low-light seasons. LEDs may be positioned near the plant canopy due to their low heat output, increasing light-use efficiency without creating thermal stress. In densely planted systems, this trait is especially advantageous for off-season vegetable production (Mitchell *et al.,* 2015).

Applications of LED Lighting in off-Season Vegetable Crops

A variety of vegetable crops may be grown off-season with the help of LED lights. Lettuce, spinach, and kale are examples of leafy crops that react well to blue-rich LED light, leading to increased biomass and improved leaf quality. Red-dominant light spectra improve blooming and fruit set in fruiting plants including tomatoes, cucumbers, and capsicums. Under ideal LED illumination settings, root vegetables and herbs also exhibit enhanced growth and consistency (Bantis *et al.,* 2018).

Energy Efficiency and Sustainability

The excellent energy efficiency of LED lighting in comparison to traditional lighting systems is one of its main advantages. LEDs have a longer operating life and use a lot less power, which lowers production costs and lessens their impact on the environment. By reducing carbon emissions and encouraging resource-efficient food production methods, particularly during off-season cropping, their economical energy usage is in line with sustainable agricultural objectives (Morrow, 2008).

Impact on Yield and Quality of Vegetables

According to studies, LED illumination enhances the quality of vegetables cultivated off-season while also increasing output. LED lighting has been shown to improve color, texture, and the buildup of health-promoting substances including vitamins, antioxidants, and phenolic compounds. These enhancements raise the market acceptance of off-season veggies and give them more value (Lin *et al.,* 2013).

Challenges and Limitations

Adoption of LED lighting is not without its difficulties, despite its benefits. Significant limitations include high initial investment costs, the requirement for technological know-how, and the optimization of light spectra for various crops. Additionally, aberrant growth responses might result from poor light control. Therefore, for LED technology to be widely used in off-season vegetable production, crop-specific research and economic evaluations are required (Mitchell *et al.,* 2015).

Future Prospects

Off-season vegetable production is anticipated to be significantly improved by developments in LED technology, such as intelligent lighting systems with sensors and artificial intelligence. Future studies are probably going to concentrate on crop-specific light formulations, lower energy usage, and combining LED lighting with precision farming techniques. These advancements will be essential to maintaining fresh vegetable availability throughout the year in sustainable farming systems (Singh *et al.,* 2015)

References

Bantis, F., (2018). Light spectrum manipulation for horticulture: A review. *Scientia Horticulturae*.

Hogewoning, S.W., (2010). Blue light dose–responses of leaf photosynthesis. *Journal of Experimental Botany*.

Kozai, T., Niu, G., and Takagaki, M. (2019). Plant Factory: An Indoor Vertical Farming System. *Academic Press*.

Lin, K.H., (2013). Effects of light quality on vegetable growth. *Agricultural Sciences*.

Mitchell, C.A., (2015). LEDs: The future of greenhouse lighting. *HortScience*.

Morrow, R.C. (2008). LED lighting in horticulture. *HortScience*.

Singh, D., (2015). Artificial lighting in controlled environment agriculture. *Journal of Plant Science*.

Taiz, L., Zeiger, E., Møller, I.M., & Murphy, A. (2015). Plant Physiology and Development. *Sinauer*.

8. AGRICULTURAL SCIENCES

Sustainable Agriculture for Food Security and Environmental Resilience: Practices, Technologies and Future Perspectives

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Abstract

Sustainable agriculture is essential for meeting the growing demand for food while conserving natural resources and protecting the environment for future generations. Conventional agricultural intensification has contributed substantially to increased food production, but it has also created challenges including soil degradation, water scarcity, biodiversity loss, excessive dependence on external inputs and greenhouse-gas emissions. Sustainable agriculture seeks to balance three major dimensions: economic viability, environmental protection and social well-being. Important approaches include conservation agriculture, integrated nutrient management, efficient irrigation, crop diversification, agroforestry, integrated pest management, organic amendments, precision agriculture and climate-smart farming. Recent advances in remote sensing, geographic information systems (GIS), artificial intelligence, sensors and digital agricultural advisory systems are creating new opportunities for efficient resource management. The FAO's *State of the World's Land and Water Resources for Food and Agriculture 2025* emphasizes that land, soil and water are under increasing pressure and that sustainable management of these resources is fundamental to future food security. Sustainable agriculture therefore requires integration of scientific innovation, farmer knowledge, appropriate policies, efficient technologies and market support to create productive, resilient and environmentally responsible food systems.

Keywords: Sustainable agriculture, food security, soil health, water conservation, precision agriculture, climate resilience, biodiversity, resource-use efficiency

Introduction

Agriculture is the foundation of food security and rural livelihoods, but increasing population, climate change, land degradation and water scarcity are placing unprecedented pressure on agricultural systems. FAO's 2025 assessment highlights that agricultural land, soil and water resources are already under severe pressure, with more than 60% of human-induced land degradation occurring on agricultural lands and agriculture accounting for more than 70% of global freshwater withdrawals.

Sustainable agriculture aims to produce adequate and nutritious food while maintaining soil fertility, conserving water, protecting biodiversity and ensuring long-term economic viability for farmers. It is therefore not simply a reduction in chemical inputs but a broader transformation of the agricultural production system.

Major Components of Sustainable Agriculture

Soil Health Management

Healthy soil is fundamental to sustainable crop production. Practices such as crop rotation, cover cropping, residue retention, reduced tillage, compost application and integrated nutrient management improve soil organic matter, microbial activity, waterholding capacity and nutrient-use efficiency.

Conservation agriculture can reduce erosion and improve soil structure while maintaining productivity. Sustainable soil-carbon management through practices such as cover crops, mulching, crop-residue management and appropriate soil amendments can simultaneously improve soil health and contribute to climate mitigation. FAO identifies improved soil-carbon management as an important pathway for climate-resilient agriculture.

Efficient Water Management

Water scarcity is becoming a major constraint on agricultural production. Sustainable agriculture therefore requires producing more crop output with less water. Drip and sprinkler irrigation, irrigation scheduling based on crop water requirements, soil-moisture sensors, rainwater harvesting and farm ponds can significantly improve water-use efficiency.

In rice production, practices such as alternate wetting and drying can reduce water consumption while also lowering greenhouse-gas emissions.

Crop Diversification

Crop diversification reduces dependence on a single crop and improves the resilience of farming systems. Crop rotation, intercropping, mixed cropping and inclusion of legumes can improve soil fertility, interrupt pest cycles and reduce production risks. Diversified systems can also provide farmers with multiple sources of income and improve nutritional security.

Integrated Pest and Nutrient Management

Integrated pest management (IPM) combines biological, cultural, mechanical and chemical methods to manage pests economically while minimizing environmental damage. Similarly, integrated nutrient management combines organic manures, crop residues, biofertilizers and judicious fertilizer application to maintain soil fertility and improve nutrient-use efficiency.

Agroforestry and Biodiversity

Agroforestry integrates trees with crops and/or livestock. It can provide additional products, improve soil conditions, reduce wind and water erosion, increase carbon storage and create habitats for beneficial organisms. FAO identifies agroforestry as an important pathway for increasing resilience to climate extremes while supporting biodiversity and soil health.

Role of Technology in Sustainable Agriculture

Modern technologies are increasingly important for sustainable agricultural development. Remote sensing and satellite imagery can monitor crop growth, soil moisture, drought stress and vegetation health over large areas. GIS can support land-use planning and identification of vulnerable agricultural areas.

Precision agriculture uses GPS, sensors, drones, satellite data and variable-rate technologies to apply water, fertilizers and pesticides according to actual crop requirements. Artificial intelligence and machine learning can further support yield forecasting, disease detection, irrigation scheduling and climate-risk assessment.

Such technologies can improve resource-use efficiency and reduce unnecessary agricultural inputs. FAO also emphasizes the importance of geospatial technologies and data-driven decision-making for integrated management of land, soil and water resources.

Climate-Smart and Resilient Agriculture

Climate change is increasing the frequency and intensity of heat stress, droughts, floods and other extreme events. Sustainable agriculture must therefore incorporate climate adaptation and resilience. Heat- and drought-tolerant varieties, modified sowing dates, water-saving irrigation, conservation agriculture, agroforestry and weather-based agricultural advisories can reduce climate-related risks.

Sustainable agriculture can also contribute to climate mitigation through soil-carbon sequestration, improved fertilizer efficiency, reduced tillage, agroforestry and efficient water and energy use. FAO identifies sustainable and resilient agrifood systems as an important pathway for simultaneously addressing climate change, biodiversity loss and food security.

Economic and Social Dimensions

Sustainability cannot be achieved through environmental measures alone. Farming practices must also be economically feasible and socially inclusive. Small and marginal farmers require access to affordable technologies, credit, quality seed, extension services, markets and reliable climate information.

FAO's *State of Food and Agriculture 2024* emphasizes that transformation of agrifood systems requires consideration of their economic, social and environmental impacts. The report estimates that quantified hidden costs of agrifood systems amount to around 10% of global GDP, highlighting the need for policies that encourage more sustainable production and consumption.

Future Perspectives

The future of sustainable agriculture will depend on integrating traditional knowledge with modern science and digital technologies. Priority areas include regenerative soil management, water-efficient agriculture, climate-resilient varieties, renewable-energy-based farm operations, circular use of agricultural residues, precision agriculture and nature-positive farming.

The 2025 FAO assessment indicates that sustainable intensification and better management of existing agricultural land can increase production while avoiding unnecessary expansion into forests, grasslands and other ecosystems.

Conclusion

Sustainable agriculture provides a pathway for achieving food security while protecting the natural resources on which agriculture depends. Its success requires simultaneous attention to productivity, soil health, water conservation, biodiversity, climate resilience, farmer income and social equity. Conservation agriculture, crop diversification, integrated nutrient and pest management, efficient irrigation, agroforestry and precision agriculture can substantially improve resource-use efficiency and resilience. The rapid development of satellite remote sensing, GIS, artificial intelligence and digital advisory systems provides additional opportunities for site-specific and data-driven agricultural management. Ultimately, sustainable agriculture should move beyond maximizing short-term production toward building productive, profitable and resilient farming systems capable of supporting present and future generations.

Latest References

FAO. (2025). The State of the World's Land and Water Resources for Food and Agriculture 2025: The Potential to Produce More and Better (SOLAW 2025). Food and Agriculture Organization of the United Nations, Rome.

FAO. (2024). The State of Food and Agriculture 2024: Value-Driven Transformation of Agrifood Systems. Food and Agriculture Organization of the United Nations, Rome.

FAO. (2025). Land, Soil and Water: Sustaining Our Precious Resources While Producing More and Better. Food and Agriculture Organization of the United Nations.

FAO. (2025). *Five Science-Backed Solutions for a Climate-Resilient Future.* Food and Agriculture Organization of the United Nations.

FAO. (2025). *Integrated Management of Land, Soil and Water Resources.* Food and Agriculture Organization of the United Nations.

FAO. (2024). The State of Food and Agriculture 2024: Value-Driven Transformation of Agrifood Systems. FAO, Rome. DOI: 10.4060/cd2616en.

IPCC. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Cambridge University Press.

United Nations. (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations, New York.

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