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Decoding Crops: The Role of Genomics in Sustainable Agriculture

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Introduction

Feeding a growing global population amid climate change, land degradation, and limited resources demands innovative solutions. Traditional farming methods alone cannot meet future food needs sustainably. Genomics, the study of an organism's complete set of DNA, offers a transformative approach to crop improvement. By unlocking the genetic code of plants, genomics enables the development of high-yielding, resilient, and resource-efficient crops. This article explores how genomics is shaping the future of sustainable agriculture through advanced breeding, genome editing, and precision farming.

Understanding Genomics: The Science Behind the Seeds

Genomics refers to the comprehensive study of the entire genetic material of organisms. Unlike classical genetics, which examines single genes and their roles, genomics provides a holistic view of all genes and their interactions. This allows scientists to understand complex traits controlled by multiple genes and environmental factors—traits such as drought tolerance, disease resistance, nutrient efficiency, and yield.

In agricultural genomics, scientists sequence the genomes of crops to identify genetic variations associated with favorable characteristics. Modern DNA sequencing technologies, such as next-generation sequencing (NGS), have made it possible to decode plant genomes rapidly and cost-effectively. These genomic sequences serve as maps, guiding breeders and researchers in identifying, selecting, and manipulating specific genes that can enhance crop performance.

Applications of Genomics in Crop Improvement

The power of genomics lies in its application to crop breeding, which has traditionally relied on time-consuming and imprecise methods. Genomics-based breeding, often referred to as marker-assisted selection (MAS) and genomic selection (GS), accelerates this process by enabling breeders to screen for genetic markers associated with desirable traits. These markers act like flags within the genome, signaling the presence of genes responsible for specific characteristics such as early flowering, high grain yield, or pest resistance.

One success story comes from rice breeding. In flood-prone regions of South and Southeast Asia, seasonal submergence can wipe out entire rice crops. Researchers used genomic tools to identify and incorporate the Sub1A gene, which confers submergence tolerance, into high-yielding rice varieties. These improved varieties, known as "scuba rice," can survive underwater for up to two weeks, protecting farmers from the devastating effects of flooding.

Similarly, in maize (corn), scientists have identified genes that regulate drought tolerance and used them to develop hybrid varieties capable of thriving in water-scarce environments. These varieties are particularly important in sub-Saharan Africa, where rain-fed agriculture is the norm, and climate variability poses a constant threat to food production.

Genome Editing: Precision Tools for Crop Engineering

Beyond selection and breeding, genomics has enabled precise genetic engineering through tools like CRISPR-Cas9, a gene-editing technology that allows scientists to make targeted changes to DNA sequences. Unlike traditional genetic modification, which often involves inserting genes from other species, CRISPR enables editing within the crop's own genome, resulting in fewer regulatory concerns and greater public acceptance.

CRISPR has been used to develop crops with improved traits, such as tomatoes that have longer shelf life, rice with increased resistance to bacterial blight, and wheat with reduced gluten content. These modifications not only enhance food quality and availability but also reduce post-harvest losses and minimize reliance on chemical treatments.

Moreover, genome editing holds promise for tackling malnutrition. Scientists have used genomic approaches to develop biofortified crops—varieties enriched with essential micronutrients. For example, "Golden Rice" contains genes that enhance vitamin A content, helping to combat vitamin A deficiency in regions where rice is a staple but nutrient diversity is low.

Enhancing Sustainability Through Genomics

Sustainable agriculture aims to meet current food needs without compromising the ability of future generations to meet theirs. Genomics supports this goal by promoting resource efficiency, reducing environmental impact, and enhancing resilience to climate stressors.

One avenue of sustainability is the development of input-efficient crops, which require less water, fertilizer, or pesticides to grow effectively. Genomic studies have identified genes that enable plants to use nitrogen and phosphorus more efficiently—two essential but environmentally problematic fertilizers. By breeding for such traits, farmers can maintain high yields while reducing runoff that pollutes waterways and contributes to greenhouse gas emissions.

Genomics also plays a role in integrated pest management (IPM). By understanding the genetic basis of resistance to pests and diseases, scientists can breed crops that require fewer chemical applications. For instance, resistance genes in cassava have been used to fight off mosaic virus, a devastating disease in Africa. These naturally resistant varieties reduce the need for insecticides and improve crop longevity.

In addition, genomics facilitates climate-smart agriculture, where crops are tailored to specific ecological zones. Using data on genetic diversity, researchers can match crop varieties to local

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conditions, maximizing productivity and resilience while preserving biodiversity.

The Role of Bioinformatics and Big Data

The success of genomics depends heavily on bioinformatics, the interdisciplinary field that uses software tools to analyze large volumes of genetic data. Sequencing the genome of a single plant generates terabytes of data. Bioinformatics helps organize this data, identify functional genes, and predict how those genes might influence observable traits.

One key application is genome-wide association studies (GWAS), where genetic data from a diverse population of plants is analyzed to find correlations between genetic markers and specific traits. GWAS has been used in crops like wheat, barley, and chickpea to identify genes responsible for drought tolerance, seed size, and root architecture.

Machine learning and artificial intelligence (AI) are increasingly being used to interpret genomic data. These tools can uncover complex patterns and make predictions about plant performance under various conditions. Combined with environmental data and satellite imagery, bioinformatics is enabling precision agriculture, where real-time decisions are guided by genetic and environmental analytics.

Global Impact and Case Studies

Around the world, genomics is making tangible impacts on agricultural systems. In India, the Indian Council of Agricultural Research (ICAR) has implemented genomics-based breeding for pulses such as chickpeas and pigeon peas, which are key sources of protein. These efforts have led to the release of early-maturing, drought-tolerant varieties, helping improve yields and farmer incomes.

In Africa, organizations like the African Orphan Crops Consortium are working to sequence the genomes of under-researched crops like teff, finger millet, and yam. These crops are crucial for nutrition and food security but have received less attention from global research institutions. Genomic tools are helping unlock their potential and boost regional self-reliance.

In the United States, public-private partnerships have driven rapid advancements in genomic technologies. The Genomes to Fields Initiative brings together scientists from universities and industry to improve corn yields using genomic prediction models. Similar efforts in soybeans, cotton, and fruits like apples and grapes have made U.S. agriculture one of the most genomics-integrated systems in the world.

Challenges and Ethical Considerations

Despite its promise, agricultural genomics faces several challenges. One is accessibility. Advanced genomic tools and sequencing platforms are expensive and require technical expertise. Smallholder farmers in low-income regions may not directly benefit unless there are deliberate efforts to make the technology inclusive and affordable.

Another concern is data ownership. As genetic information becomes a valuable commodity, questions arise about who owns the data and who benefits from it. Farmers, indigenous communities,

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and developing nations need to have a voice in how their genetic resources are used and commercialized.

Public perception of genome editing and biotechnology also remains mixed. Although CRISPR is more precise and less controversial than older GMOs, regulatory frameworks differ by country, and public education is crucial. Transparent communication about risks, benefits, and ethical considerations will help build trust in genomics-based solutions.

The Future of Genomics in Agriculture

Looking ahead, the future of agricultural genomics is intertwined with advances in computing, environmental science, and biotechnology. Pan-genomics, the study of the full genetic diversity within a species, is providing even deeper insights into how crops adapt to different environments. Synthetic biology may allow us to design entirely new biological pathways in plants, further expanding their capabilities.

Integrating genomics with geospatial data, remote sensing, and climate forecasting could enable ultra-precise agricultural interventions. Farmers might one day receive genotype-based recommendations for seed selection based on real-time soil and weather data, dramatically improving efficiency and sustainability.

Global cooperation will be essential. Sharing data, building open-source genomic platforms, and strengthening partnerships between governments, research institutions, and the private sector will ensure that genomics serves not only industrial agriculture but also smallholder and subsistence farmers worldwide.

Conclusion

Genomics is redefining agriculture. By decoding the genetic makeup of crops, scientists are opening new pathways to increase productivity, reduce environmental impact, and build resilience against climate shocks. The promise of genomics lies not only in higher yields or better nutrition but in creating a food system that is intelligent, responsive, and sustainable.

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Transforming Farming: Uttar Pradesh's Strategic Crop Planning for Sustainability

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Agriculture is considered as the backbone of Indian economy that contributes not only to employment but also had a significant role in economy. After Independence, to address different challenges such as food security, the green revolution was begun in late 60's that hugely increased the production and productivity of crops by applying various inputs such as fertilizers. In the race of increasing production, farmers ignore the soil health and water extraction quantity. As a result of mistakes had done in past, todays, soil losses its fertility and ground water table deplete many folds. Nowadays, Punjab, Haryana, and Uttar Pradesh also faces the problem of water scarcity as well as soil deterioration which are the key states of the green revolution. The climate change can also further boost these problems which combinedly threaten the food security of the growing population of world. The world now changes the approach of cultivation to the increase in productivity by maintaining sustainability and conserving resources.

The agriculture has the prominent role in Uttar Pradesh economy since green revolution in sustaining the farmers income as well as India's food security. Recently, Uttar Pradesh government aimed to increase the kharif foodgrains and oilseeds production by 12 percent this year (2025) targeted 293 lakhs tones against 260 lakhs tones last year. The traditional cultivation practices increase unsustainability against the challenges such as lack of water, climate change and soil deterioration. To tackling these issues state focuses on the improved crop planning, increase the production area, water infrastructures, market strategies, and farmers training programs to ensures higher production, resource efficiency and climate resilience. Uttar Pradesh is in a way to transform their agriculture by integrating precision farming, crop diversification and improving infrastructure for ensuring better future for their farmers.

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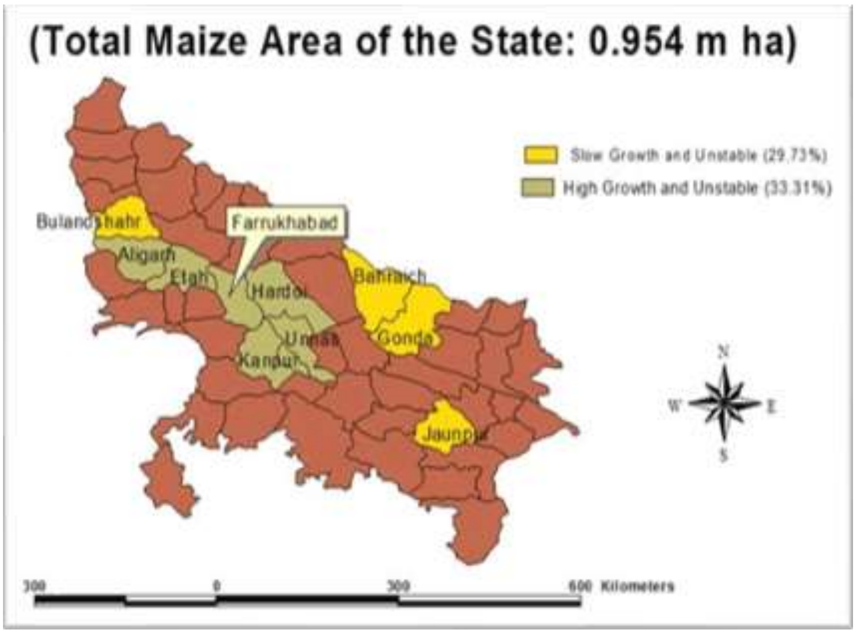
The Strategies, Government initiatives and emerging trends to achieve these targets are further discussed in this article.

1. **Strategies for transforming agriculture.**

1.1 Crop diversification and sustainable farming practices.

The change in crop rotation by increasing the production of crops required less water as alternative of water intensive crop such as rice. Uttar Pradesh government under "Rapid Maize development Scheme" increases the area under maize by 200000 hectares towards achieving its target of 3.2 million tone production of maize by 2027. It is also noticed that 15 percent of area under paddy are changed to oilseeds production that improves the soil fertility and structure which ensures sustainability. Intercropping is practices widely accepted by the farmers of Uttar Pradesh, a study found that around 33 percent farmers adopt intercropping that boost their income up to 93 percent and mean increased in productivity are around 25 percent. A study indicates that citronella with maize at 100 percent RDF gives highest profit.



Uttar Pradesh government initiates five years campaign to promote organic farming and biofertilizers. The opening of 10 biofertilizers production units across the state that benefits nearly 30,000 farmers also further strengthen their targets. To conserve soil fertility around 2 crores are allocated by state to increase biofertilizer production and research infrastructures.

1.2 Water conservation and management.

The one of the major beneficiaries of Pradhan Mantri Krishi Sinchayi Yojana is Uttar Pradesh that promote micro irrigation facilities by reducing the installation cost through various incentives up to 55 percent for small and marginal farmers and 45 percent for other farmers provided by the government. Around 3.5 lakhs farmers in Uttar Pradesh adopt micro irrigation and total area coverage expands to 3,55,116 hectares in last five years. Apart, rainwater is also an alternative source of irrigation. The government shows their willing in construction of 8500 ponds till next years to conserve water and aligned with "Farm Pond Scheme" under National Agricultural Development Scheme. The ground water recharge is also a way for sustainable future aimed slowly increase in ground water table. In 2019, Uttar Pradesh government mandates rainwater harvesting in commercial and residential building and construct pits to revive aquifers under Uttar Pradesh Ground Water Management & Regulation Act (2019).

1.3 Integrating technology and focusing precision farming.

In 2023, digital agriculture export promotion council was established to helps farmers on accessing AI driven advisory services and precision farming tools. Soil health card scheme that covers around 2.5 crores farmers in Uttar Pradesh also helps in precision farming by soil

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analysis that saves excess input application. The companies such as AgriWings focuses on spraying using drone that are affordable to farmers. It helps in precise spraying of pesticides and herbicides which improves the efficiency and conserve the inputs.

2. Government initiatives for boosting agricultural growth.

The government supports farmers to transforming agriculture into sustainable or modern approach by two ways i.e., by providing financial supports, through development of skill and capacity building, and infrastructure building.

2.1 Financial assistance.

Firstly, Government should ensure the proper prices will be given to farmers for their produce by the mechanism of Market selling price (MSP). Secondly, Farmers should get the incentives through different direct benefits transfer schemes such as Agri Stacks UP portal, PM kisan. Thirdly, subsidies for farmers through various schemes by government such as UP Krishi Upkaran Subsidy Yojana (2024) that provides about 50 percent subsidy on Agricultural equipment like tractors, seeders, sprayers. Lastly, Government should also provide insurance on crops and credit at low interest rates. Schemes such as Pradhan Mantri Fasal Bima Yojana provide insurance at low premium rates i.e., 2% in kharif and 1.5% in rabi, Kisan Credit Card Scheme through which farmers can take loan up to 3 lakhs at very low interest rate i.e., 4 percent.

2.2 Skill development and capacity building.

Modern agricultural practices need high levels of skills to operate different technologies and analyzing data to made proper planning. Integration of traditional knowledge of farmers and modern scientific methods of farming can be able to enhance sustainability, productivity and profitability. Over one million farmers are trained in precision agriculture in Uttar Pradesh. Towards capacity building of farmers Uttar Pradesh government and other organizations ran different training programs for farmers such as "Million Farmers Schools" which focus on increase familiarity of famers with scientific farming methods, soil health and crop insurance. "Meadow Agricultural Training" also organize online or offline training program on horticulture, precision farming, plant protection and sustainable agriculture for farmers and researchers.

Agri startup stakeholders connect program (2024), AI driven Agri startups initiative (2024) are some efforts of UP government towards providing fundings, trainings, attract investments, network buildings and so on that boost their Agri entrepreneurs ultimately, increase farmers income through small or big startups.

2.3 Strengthening Agri infrastructures.

The government, on other hand, also strengthening agricultural infrastructures by considering sustainability aspects. Uttar Pradesh government established 5 seed parks that provide High yield variety, drought tolerant seeds. It also encourages processing unit development that reduces the post-harvest losses, and increase focus on direct farmers market linkage.

3. Emerging trends shaping Uttar Pradesh Agricultural future.

3.1 Climate resilient cropping system

Transition towards climate resilient practices Uttar Pradesh planted more than 1 crore trees as Agroforestry initiatives, which sequester 2.5-million-ton carbon per year, that promote state aimed at reaches 20 percent green cover by 2030. Along with agroforestry, government also focus on heat tolerant, drought resistant variety and improved maize hybrid to mitigate climate change impacts and water scarcity problems.

3.2 Digital marketing access and supply chain innovation

Over 125 mandis and 3.3 million farmers of Uttar Pradesh are registered in eNAM platform that ensure better price, online trading and quality assurance. Over 3000 cold storage facilities in Uttar Pradesh are established

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through continues efforts of government licensing and subsidies that minimize post-harvest losses and supporting food security.

3.3 Biofuels and Agri energy sector

The contribution of government also increases in energy and biofuel sectors through Agri-waste utilization for biofuel which promotes crop residues into biofuels like production of ethanol from maize. Bio-energy board of Uttar Pradesh supports growing of biofuel crops such as Neem, Karanja, Mahua, and Jatropha. Apart, government also focus on Agri tech services, such as AI driven precision farming tools, as well as green energy promotion through solar powered irrigation and biogas plants that reduce reliance on fossil fuels.

Uttar Pradesh is a key player in Indias food self-sufficiency. By considering todays problem, the transition of agriculture is a need of time. Integration of various technology, shift in cropping pattern and practices will enhance the productivity, sustainability and health. The growing population of world needs more production to feed for long time which requires the soil health and other resources to sustain for long run. Uttar Pradesh government target to increase kharif production by 12 percent shows their concern about growing population whereas, their planning indicates their responsiveness towards conserving resources, environment and maintain sustainability.

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Women-Led Millet Startups: Driving Innovation and Food Security

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Millets, once considered "poor man's food," are now gaining recognition as superfoods due to their high nutritional value, gluten-free nature, and environmental sustainability. Women entrepreneurs are increasingly venturing into millet-based startups, creating innovative value-added products, and addressing food security challenges. Their contribution is promoting millet consumption, fostering self-reliance, enhancing rural livelihoods, and driving economic growth.

Women-led millet startups are emerging as powerful innovation and food security drivers, particularly in rural and semi-urban areas. With the growing global demand for healthier and sustainable food choices, millets are gaining attention due to their nutritional richness, drought resilience, and climate adaptability. This article explores how women entrepreneurs are transforming millet processing and value addition into profitable enterprises, promoting food security, empowering rural communities, and contributing to sustainable agriculture. The challenges, opportunities, and success stories of women-led millet startups are highlighted, offering insights into their role in reshaping the food industry and fostering socio-economic empowerment.

The Growing Significance of Millets in Food Security

Millets such as sorghum, pearl millet, foxtail millet, finger millet, kodo millet, and barnyard millet are rich in dietary fiber, essential amino acids, vitamins, and minerals. Their drought resistance and short growing cycle make them ideal for food security in regions prone to erratic weather patterns. The United Nations declared 2023 as the International Year of Millets, highlighting their role in combating hunger and malnutrition.

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Nutritional and Food Security Benefits of Millets

- **Nutritional powerhouse:** Millets are rich in iron, calcium, magnesium, and antioxidants, aiding in the fight against anemia and micronutrient deficiencies.
- **Climate-resilient crop:** Millets require less water, making them ideal for arid and semi-arid regions, thereby contributing to agricultural sustainability.
- **Food diversification:** Millet startups promote dietary diversity, reducing reliance on wheat and rice, thereby enhancing food security.

Women Entrepreneurs in Millet Startups: Pioneering Innovation

Women-led millet startups are spearheading innovation by introducing unique, value-added millet-based products that cater to changing consumer preferences. These startups focus on convenience, nutrition, and shelf stability, offering ready-to-eat, ready-to-cook, and functional food products.

Innovative Millet-Based Products by Women Entrepreneurs

- **Bakery and Snack Items:** Millet-based bread, muffins, cookies, and crackers.
- **Gluten-Free and Healthy Snacks:** Millet chips, puffed millet snacks, and granola bars.
- **Functional and Health Products:** Millet-based diabetic-friendly foods, high-protein energy bars, and baby food.
- **Traditional and Instant Mixes:** Ready-to-cook millet dosa, idli mixes, and instant khichdi packs.

Impact on Women's Socio-Economic Empowerment

Women-led millet startups are transforming rural economies by creating job opportunities and empowering women farmers and processors. These initiatives foster financial independence, skills development, and decision-making power among women.

Key Socio-Economic Impacts

- **Income Generation:** Millet processing units enable rural women to generate a sustainable income by producing and selling value-added products.
- **Skill Development:** Women gain training in **processing, packaging, marketing, and business management**, enhancing their entrepreneurial skills.
- **Financial Inclusion:** Women-led startups access government schemes such as **Rashtriya Krishi Vikas Yojana (RKVY)** and **Agricultural Infrastructure Fund (AIF)** for financial support.
- **Community Development:** These startups promote local procurement, benefiting small-scale farmers and boosting regional economies.

Challenges Faced by Women-Led Millet Startups

Despite the growing success, women entrepreneurs in the millet sector face several challenges:

- **Limited Access to Capital:** Women often struggle to access loans and financial support for expanding their millet processing units.
- **Marketing and Branding Issues:** Lack of effective branding and limited marketing channels hinder product reach.
- **Technological Barriers:** Limited access to advanced processing and packaging technology reduces efficiency and product quality.
- **Policy and Licensing Challenges:** Obtaining **FSSAI licensing** and adhering to food safety standards can be complex and time-consuming.

Opportunities for Women in Millet Entrepreneurship

The rising consumer awareness of healthy and sustainable foods offers immense growth potential for women-led millet startups.

Key Opportunities

- **Government Support and Schemes:** Initiatives like National Food Security

- Mission (NFSM) and Pradhan Mantri Kisan Sampada Yojana (PMKSY) offer grants and subsidies for millet processing startups.
- **Export Potential:** With the increasing global demand for gluten-free and healthy foods, women-led startups have the potential to tap into international markets.
- **E-commerce and Digital Platforms:** Online marketplaces enable women entrepreneurs to reach wider consumer bases.
- **Value Addition and Innovation**: Developing convenient, nutritious, and functional millet products can boost sales and market share.

Conclusion

Women-led millet startups are driving innovation, promoting food security, and empowering rural communities. By leveraging government support, technological advancements, and innovative marketing strategies, these startups are transforming the millet sector into a profitable and sustainable industry. Promoting and supporting such women-led ventures is vital for enhancing food security, reducing gender disparities, and building resilient rural economies.

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Heavy Metals: Soil Contamination and Remediation

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Heavy metals are elements with high atomic weight, density at least five times greater than water, can be toxic even at low concentrations and tend to persist in the environment. The most common heavy metals that contaminate soils include lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), nickel (Ni), zinc (Zn) and copper (Cu).

Sources of heavy metal contamination

- Mining and smelting
- Processing and manufacturing
- Production and disposal waste of chemical industries
- Agrochemicals like pesticides containing heavy metals as ingredients or contaminants
- Sewage sludge and manure application to soils
- Vehicular emissions
- Construction and demolition
- Improper waste disposal and landfills
- Geogenic sources or weathering of parent rocks
- Volcanic activity, emissions and ash deposits

Mechanisms of soil contamination

Atmospheric deposition: Heavy metals can be transported by wind and deposited on soil surfaces.

Leaching and runoff: Toxic metals can move through soil profile or transported along with water.

Direct application: Agricultural and industrial applications can introduce metals directly into the soil.

Effects of heavy metals contamination on soil properties

- *Soil pH:* Heavy metals can alter soil pH and affect nutrient availability.
- *Cation exchange capacity (CEC):* Metals can compete with essential nutrients, reducing cation exchange capacity ultimately the soil fertility.
- *Microbial activity inhibition:* Heavy metals can be toxic to beneficial soil microorganisms, disrupting soil organic matter decomposition and nutrient cycling.
- *Microbial community shifts:* Due to differential tolerance of micro-organisms to various metals,

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changes in microbial population and diversity take place.

- *Plant toxicity:* Heavy metals can inhibit seed germination, root development, and overall plant growth and productivity.

Effects of heavy metals contamination on human health

Bioaccumulation: Plants can uptake heavy metals along with nutrients, which then enter the food chain and causes biomagnifications.

Direct exposure: Direct contact and inhalation from contaminated soil can lead to skin irritation, rashes and respiratory issues.

Endocrine disruption: Some heavy metals can interfere with hormone functioning, leading to reproductive and developmental issues.

Immune system suppression: Heavy metals may weaken the immune system, making individuals more susceptible to infections and diseases.

Along with these common health issues, specific effects of some toxic heavy metals include:

I. *Lead (Pb):* This neurotoxin can cause developmental issues in children including reduced IQ, attention disorders and behavioral problems. In adults, it may lead to hypertension, kidney damage and reproductive issues.

II. *Cadmium (Cd):* This carcinogen can cause kidney damage, bone demineralization, lung and prostate cancer.

III. *Arsenic (As):* Long-term exposure of arsenic may lead to skin lesions, cardiovascular diseases and increased risk of skin, bladder and lung cancer.

IV. *Mercury (Hg):* Mercury affects the nervous system, leading to memory loss, cognitive and motor dysfunction.

V. *Chromium (Cr):* Chromium is highly toxic and can cause respiratory problems, weaken immune system and increase the risk of lung cancer.

Remediation of contaminated soil

Remediation methods of heavy metals contaminated soil aim to mitigate the environmental and health risks associated with heavy metal by reducing, removing or immobilizing the contaminants. These methods involve various physical, chemical and biological mechanisms as per descriptions given below:

A. <u>Physical methods</u>

1. ***Soil excavation and removal:*** Contaminated soil is physically removed, treated and transported to safe landfill.
   Advantages: Immediate removal of contaminants.
   Disadvantages: High cost, disruption to the site, and potential exposure risks during transportation.
2. ***Soil washing:*** Contaminated soil is washed with water or chemical solutions to dissolve and remove heavy metals.
   Advantages: Effective for wide range of metals and contaminants.
   Disadvantages: Generation of secondary waste (wash water), high cost, and complex treatment processes.
3. ***Thermal desorption:*** Soil is heated to volatilize and remove contaminants.
   Advantages: Effective for volatile and semi-volatile contaminants.
   Disadvantages: High energy consumption, not suitable for non-volatile heavy metals.

B. <u>Chemical methods</u>

1. ***Stabilization/solidification:*** Addition of binding agents (cement, lime, fly ash etc.) to the contaminated soil to immobilize heavy metals.
   Advantages: Relatively low cost, reduces mobility and bioavailability of metals.
   Disadvantages: Long-term stability may vary, potential volume of treated soil increase.
2. ***Soil amendments:*** Adding materials like phosphate, biochar or organic matter to soil to immobilize heavy metals.
   Advantages: Improve soil properties, cost-effective, can be tailored to specific contaminants.
   Disadvantages: Effectiveness may vary, long-term stability issues.

3. ***Chemical extraction:*** Using chelating agents (EDTA, HA, FA or citric acid) or acids to extract heavy metals from contaminated soil.
   Advantages: Effective for specific heavy metals.
   Disadvantages: High cost, potential secondary contamination, environmental impact of chemicals used.

C. **Biological Methods**

1. ***Phytoremediation:*** Using plants to absorb, uptake or degrade heavy metals from the soil.

Techniques.

Phytoextraction: Plants uptake and accumulate toxic metals in their tissues.

Phytostabilization: Plants immobilize toxic metals in soil by the binding action of roots or root exudates.

Phytovolatilization: Plants uptake heavy metals and releases them into atmosphere in a less harmful gaseous form.

Advantages: Environmentally friendly, aesthetically pleasing, improve soil structure.

Disadvantages: Slow process, limited to surface soils, effectiveness depends on plant species and metal type.

2. ***Bioremediation:*** Using microorganisms to transform or detoxify heavy metals.

Techniques

Bio-augmentation: Adding specific microorganisms to degrade or immobilize heavy metals.

Bio-stimulation: Enhancing the activity of existing soil microorganisms by adding nutrients or altering the soil environmental conditions.

Advantages: Cost-effective, minimal environmental impact.

Disadvantages: Slow process, effectiveness depends on soil conditions and metal types.

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Climate-Smart Agriculture: Strategies for Resilient Crop Production

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Introduction

Climate-Smart Agriculture (CSA) is a visionary and holistic strategy for changing and shifting agricultural systems to enhance food security in the context of a changing climate. It involves a framework of principles and practices that collectively meet the triple goals of promoting agricultural productivity and income, resilience to climate change, and reducing or eliminating greenhouse gas (GHG) emissions when feasible. This strategy not only serves the farmers and food systems but also adds to the overall ends of sustainable development and climate action.

In contrast to more conventional farming practices that tend to deal with productivity and sustainability in an isolated manner, CSA brings them together in a harmonized approach. It also understands that there isn't one panacea that can deal with the complex problems of climate change. Rather, it advocates for a range of multiple, locally evolved technologies, institutions, and policies. These could be better crop varieties, conservation agriculture, agroforestry, integrated pest management, climate information services, efficient irrigation, and financial instruments like weather-indexed insurance. Bhattacharyya *et.al.* 2020.

CSA applies to all the main sectors of agriculture-field crops, livestock, Injects, and fishery-and is adapted to the distinct needs of individual communities and agro-ecological regions. It enables well-informed decision making and the use of science-based resources so adaptive responses can take place in a scientifically supported manner along with on-ground realities. The objective is not just to strengthen agriculture against the effects of climate change but also to ensure that it can continue as a sustainable livelihood means for hundreds of millions of individuals on the planet.

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Why is Climate-Smart Agriculture necessary?

Agriculture is one of the most climate-vulnerable sectors of the global economy. The rising incidence and severity of extreme weather events-such as droughts, floods, and heatwaves-present direct threats to crop yields, livestock health, and food production overall. For smallholder farmers and poor people, whose very livelihoods depend on agriculture, the stakes are at their highest.

Meanwhile, agriculture itself remains a major driver of climate change. It contributes a big percentage of world GHG emissions, mostly from methane from livestock, nitrous oxide from fertilized fields, and carbon dioxide from land use, such as deforestation. Thus, making agriculture a climate-smart industry is essential not only for adaptation but also for world mitigation purposes.

Moreover, the global population is anticipated to reach more than 9 billion by 2050, exerting unparalleled pressure to grow more food with fewer inputs. Land and water are getting shorter, and competition for them is heightening. With this backdrop, CSA presents a way of fulfilling future food needs and yet maintaining the natural resource base as well as safeguarding ecosystems.

Source- https://csaguide.cgiar.org/csa/what-is-climate-smart-agriculture

Climate-Smart Agriculture is crucial for the development of a climate-resilient agricultural sector that is capable of enduring climate shocks and stresses while still supporting economic development and poverty reduction. Through enhanced resource efficiency, production system diversification, and adaptive capacity, CSA enables long-term productivity and environmental sustainability. In the end, it offers a realistic framework for attaining food security and climate resilience in a world fraught with uncertainty and change. De Pinto *et.al.* 2020

2. Major Principles of Climate-Smart Agriculture

Climate-Smart Agriculture is based on the foundation of four major principles that collectively foster sustainable, resilient, and low-emission agriculture development. The principles inform the designing and implementation of climate-resilient farming systems to suit local environments.

1. Productivity

Climate-Smart Agriculture (CSA) aims to sustainably boost productivity by producing more food, fiber, and fuel per unit of land, water, and nutrients. Key strategies include adopting high-yield, stress-resistant crop varieties, improving input efficiency via precision agriculture, and using agroecological practices like crop rotation and intercropping.

2. Adaptation and Resilience

Climate-Smart Agriculture (CSA) enhances adaptation and resilience by helping farming systems cope with climate extremes like droughts, floods, and temperature shifts. Key strategies include crop diversification, integrating livestock and forestry, improving climate information and early warning systems, and adopting flood- and drought-tolerant crop varieties.

3. Mitigation

Climate-Smart Agriculture (CSA) supports climate change mitigation by reducing greenhouse gas emissions and enhancing carbon storage. Key practices include conservation agriculture and reduced tillage to preserve soil carbon, agroforestry and cover cropping to boost carbon sequestration, and better management of manure and fertilizers to cut emissions.

4. Socioeconomic and Institutional Support

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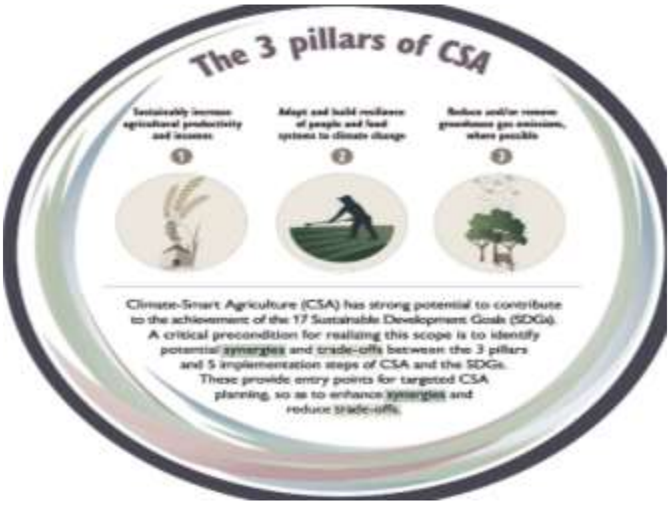
Effective Climate-Smart Agriculture (CSA) requires strong socioeconomic and institutional support. Key elements include building the capacity of farmers, extension workers, and communities; implementing supportive climate and agricultural policies with targeted incentives; and promoting risk-sharing tools such as weather-indexed crop insurance.



Source- https://medium.com/@saleemj712/climate-smart-agriculture-techniques

3.CSA Strategies for Resilient Crop Production

Climate-Smart Agriculture (CSA) advocates for sustainable and adaptive crop production measures to address the negative effects of climate change. The measures are meant to improve resilience, increase productivity, and make the environment sustainable. The following are some of the major CSA approaches adapted for resilient crop production.

1. Crop Diversification

Crop diversification is a pillar of resilient agriculture. By cultivating a range of crops instead of a single crop, farmers minimize their exposure to climate-related hazards like pests, drought, or market shocks. This practice enhances soil fertility through methods such as crop rotation, intercropping, and mixed farming that promote ecological stability and nutrient cycling. For example, rotation of legumes with cereals can enrich the soil with nitrogen naturally, minimizing the use of synthetic fertilizers. In addition, diversified cropping systems provide food and income security, particularly under uncertain weather conditions. Singh,*et.al.*2017.

2. Climate-Resilient Varieties

The use of climate-resilient crop varieties is essential to withstand adverse environmental conditions. Some examples include seeds that are tolerant of drought, floods, heat, and early maturing. They are frequently developed for resistance to diseases, thereby minimizing the use of chemical inputs. One good example is Swarna-Sub1 rice, a flood-tolerant variety capable of staying alive in water for two weeks, highly suitable for flood-prone conditions. These types of varieties ensure improved yields even under stress, thus stabilizing food production across changing climates.

3. Water-Smart Practices

Water management plays a very important role in climate-smart agriculture. Micro-irrigation technologies such as drip and sprinkler irrigation supply water directly to plant roots, minimizing water loss due to evaporation or runoff. Rainwater harvesting methods such as farm ponds and roof catchment harvest rainwater to be used during periods of dry weather. Also, irrigation scheduling using real-time weather information and crop requirement improves water-use efficiency. Not only do these measures save water, but they also maximize crop performance with restricted water supply.

4. Soil Management

Soils that are healthy underpin resilient agriculture. CSA focuses on soil conservation using reduced or zero tillage, which saves soil structure and organic matter. Mulching and cover cropping avoid erosion, weed suppression, and soil moisture conservation. Organic amendments such as biochar, compost, and green manure improve soil fertility and microbial activity, and subsequently, soil health improves over the long term. These initiatives contribute to the development of a strong root environment, and this enhances the resilience of crops to climate stress.

4.CSA Technologies and Innovations

Climate-Smart Agriculture (CSA) uses advanced technologies and new techniques to increase farm productivity, improve climate change resilience, and minimize environmental degradation. These technologies not only allow farmers to cope with unpredictable weather patterns but also ensure sustainable resource utilization. Some of the notable CSA technologies and tools contributing greatly to the sector are listed below.

1. Precision Agriculture

Precision farming is transforming agriculture by combining GPS, sensors, drones, and IoT (Internet of Things) technologies to monitor crop and soil conditions with high accuracy. Farmers can make the best decisions regarding the right time and amount of inputs such as water, fertilizers, and pesticides based on real-time data. This provides an optimized use of resources, saving costs, and boosting productivity. For instance, variable rate technology (VRT) enables one area of a field to be treated differently, enhancing efficiency and reducing damage to the environment.

2. ICT Tools and Early Warning Systems

Information and Communication Technologies (ICT) are central to CSA by providing timely and appropriate information to farmers. Mobile apps give localized weather forecasts, market prices, agronomic recommendations, and government scheme updates. SMS notifications alert farmers to pest or disease infestations, enabling early intervention. Satellite imagery and remote sensing also enable real-time crop health monitoring and yield prediction. All these empower farmers to base their decisions on climate information, hence minimizing risk and enhancing farm resilience.

3. Integrated Pest and Disease Management (IPDM)

IPDM is an environmentally friendly method of pest and disease management by integrating biological control, resistant varieties, and cultural methods like crop rotation and intercropping. It focuses on reducing the use of chemical pesticides to avoid environmental degradation and pest resistance. IPDM promotes biodiversity, ecological balance, and long-term health of crops. IPDM integrates local knowledge with scientific practices to offer sustainable management solutions specific to particular agro-ecological zones.

4. Conservation Agriculture (CA)

Conservation Agriculture encourages sustainable land management through minimum soil disturbance (reduced tillage or no-till), permanent soil cover with cover crops or crop residues, and diverse crop rotations. These practices enhance soil structure, water retention, and organic matter levels, contributing to improved moisture conservation and carbon storage. Conservation Agriculture builds sustainable farming systems that resist droughts, floods, and climate-related stresses.

5. Institutional and Policy Support for CSA

Institutional arrangements and policy support are central to upscaling Climate-Smart Agriculture (CSA). Although technological breakthroughs are essential, their effective uptake relies to a great extent on supporting policies, financial systems, capacity development, and community engagement. These institutional pillars guarantee that CSA is delivered to small-scale farmers and implemented sustainably in different regions. Venkatramanan *et.al.* 2020.

1. Government Policies

National and state-level policies are essential to mainstream CSA. Governments have started incorporating CSA goals in larger development agendas. For example, India's National Action Plan on Climate Change (NAPCC) and State Action Plans on Climate Change (SAPCCs) focus on climate adaptation and sustainable agriculture. Policy support also involves investment in climate-resilient infrastructure like irrigation systems, rural roads, and storage facilities that minimize vulnerability and post-harvest loss.

2. Financial and Insurance Instruments

Smallholders' access to finance is essential to take up CSA practices. Climate risk insurance protects farmers from losses in case of extreme weather conditions such as droughts or floods. Subsidies and incentives for precision farming equipment, micro-irrigation systems, and renewable energy also promote the adoption of technology. Schemes such as climate finance and carbon credit market participation may offer long-term funds for CSA projects.

3. Capacity Building

Educating farmers is critical to successful implementation of CSA. Farmer Field Schools, extension services, and climate literacy training programs can develop technical expertise and adaptive capacity. Research centers and innovation centers also contribute to localized, climate-resilient technology and practice development. Lipper *et. al.* 2014.

4. Community-Based Approaches

Local societies are at the heart of climate resilience. Participatory planning, farmer involvement in decision-making, guarantees a context-relevant CSA strategy. Farmer Producer Organizations (FPOs) enhance collective bargaining and market access. Incorporating indigenous perspectives together with scientific methodology enhances adaptation strategy and grassroots ownership.

Conclusion:

Climate-Smart Agriculture (CSA) is an essential strategy for dealing with both food security and climate change challenges. By addressing simultaneously increased productivity, resilience, and greenhouse gas mitigation, CSA represents a sustainable approach to agriculture in the contemporary world. It is not a one-fits-all approach, but rather an adaptable, integrated system adjusted to local conditions. Effective application of CSA calls for active engagement by farmers, researchers, policymakers, and the private sector. Encouraging innovation, inclusive policy, and community involvement is crucial for long-term agricultural sustainability and climate resilience, particularly for vulnerable smallholder farmers in various agro-ecological zones.

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A glimmer of hope for irrigation in Bundelkhand – Center Pivot Plant system

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Introduction

The center pivot irrigation system is another name for the pivot plant irrigation system. It is also known as a water wheel or circle irrigation. This system was first time introduced by Frank Zybach who is Colordo farmer. It's invented 1940s and first patent filed in 1952. A center pivot irrigation system is made up of movable pipes that revolve around a water supply-connected central pivot point. Because of their high efficiency, high uniformity, capacity to water uneven terrain, and low costs of capital, maintenance, and management, center pivot irrigation systems are the most widely used sprinkler irrigation systems worldwide. This overhead sprinkler system is made up of a lengthy pipeline that is held up by a movable tower that revolves around a stationary center point. . Water is delivered to the pivot point sources of the pivot plant well, rivers, reservoir, and pump set via a network of sprinklers connected along the pipeline. Compared to a conventional flood irrigation system, this technique is much more effective in reducing water loss through runoff. In the Jalaun district's Ragoli village, the Bundelkhand pivot plant system was just established in 2025. It's first irrigation system for pivot plants. It's cover around 30 hectare land for irrigation. But pivot plant system cover large area up to 50 hectare (125 acres) or more. It's depending on length of pipeline. It's divided 5 main part pivot point, control panel, drive units, spans and electrical control boxes. Efficient irrigation management provides benefits such as saving fresh water and energy, reducing nutrient leaching, increasing crop yield and grain quality, and maximizing return on investments. Globally, the center pivot market is dominated by North America (50% of system). Under the Prime minister Agriculture Irrigation Scheme (Per drop more drop) center pivot plant system is included.

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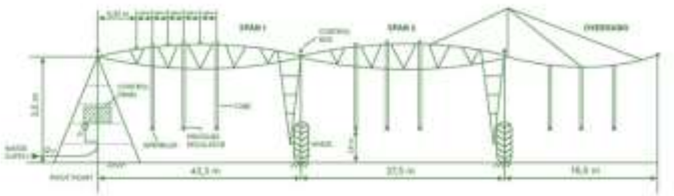

How to useful for Bundelkhand farmers

The average rainfall in Bundelkhand is 657 - 1146mm, so there is drought here throughout the year. The groundwater level here is very low, deep bore-wells are required for irrigation. Canals for irrigation are nominal, so the farmers here are able to take only two crops in a year and the farmers here are dependent only on pulse crops which require less water. Farmers here cannot grow crops that require more water. With the arrival of this pivot plant system, farmers will be able to take three to four crops in a year, which will increase the income of farmers and the objective of the Government of India is to double the income of farmers. Here farmers will be able to grow crops like paddy and sugarcane. Due to which the income of the farmer and the government will increase. The depiction of Bundelkhand farmers sitting on parched land and gazing at the sky will transform to show them standing in vibrant, green fields after the arrival.

Table: - Water use efficiency according to irrigation method

Irrigation method	Drip irrigation	Sprinkler irrigation	Flood irrigation	Surface irrigation	Center Pivot
Water use efficiency	95- 100	80-85	60-70	50-60	85-95

Above table shows the centre pivot plant irrigation is second batter irrigation method according to water use efficiency.

Advantage

1. Its automatic, farmers need not to present in the farm at the time of application of water he can watch live footage of it on own smart phone and computer.
2. Increased crop yield because consistent watering help prevent stress and disease.
3. Low Labour cost because its operate throw automatic.
4. Less water losses because in this function we use sprinkler.
5. Higher return on investment.
6. Saved time, we are easily control of pivot system.
7. Batter pest management because we are applying throws this system insecticide and pesticide herbicide and fertigation such as urea application.
8. Its better option plane area and valley area, dry area desert area where is low ability of water such as Bundelkhand area and Rajasthan desert area.
9. Reduced soil erosion.
10. Farmers take multiple crops in any season without any difficulty. It's only 60% water requirement of traditional method. Farmers grow 3-5 crops in year.

Disadvantage

1. Initially cost is high farmer cannot be afford. Its cost US $20000- $80000 per plant (In Indian Rupees 1700000 – 6800000).
2. Its cover only a circle area.
3. Maintenance requirement such cleaning nozzles, replacing hoses cleaning filters. Iron pipe rust is a big problem.
4. Skill requirement, Electricity requirement and water requirement.

Conclusion

Center pivot plant irrigation system is mostly plant in large farm and its helpful increasing farmer's income. Farmer can grow 3 and 4 crop in a year. Because it's more than 85% -95% water used efficiency. Its initial cost is high, farmers cannot not afford. Then we can say that a happy farmer means a happy country because without happy farmers, it is difficult to imagine a prosperous country.

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Healthy nursery raising and use of modern varieties- A way to increase yield potential in rice

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Rice is second staple food of India which share 41 % of total food grain production from 35% of the national food grain area (Bandumula *et al*., 2022). So, it has very important role in national food security (Shankar *et al*., 2025). India is second largest producer of rice having production of 131 million tons on largest area of 44 million hectares (Manohar *et al*., 2017). However, the rice productivity in India is 3.37 tons per hectare whereas the world average is 4.25 tons per hectare (Nayak *et al*., 2019). It is estimated that the rice requirement of India by the year 2050 would be more than 50% due to population increases (Pathak *et al*., 2020; Nayak *et al*., 2024). To fulfil the huge demand of food, rice production must be increased. The area, production and productivity of rice is not stable over period due to different causes. The primary causes for low yield potential of rice are cultivation on marginal to submarginal soils, poor preparatory tillage and ignorance in intercultural operations, non-specific management of pests, improper sowing time, improper seed rate, multiple nutrient deficiencies, depleting ground water, higher cost of cultivation, labor scarcity, faulty irrigation practices, unavailability of quality seed of modern varieties during sowing time and lack of healthy nursery raising. Other emerging challenges of rice production and productivity are ground water depletions, soil degradation, environment pollution, climate change, declining input use inefficiency and use of agricultural land in urbanization (Singh *et al*., 2021). For enhance rice production and productivity, broadly there may be two options, one is horizontal increasing area of rice production, and another option is vertical implementation of yield enhancing technologies (Bandumula *et al*., 2022). Among these, unavailability of quality seed of modern varieties during sowing time and lack of healthy nursery raising are very important factors which directly affects to rice production and productivity.

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Healthy Nursery Raising:

During selection of land for raising nursery of a particular variety, in previous season rice crop should not be grown in land selected to avoid varietal mixture due to volunteer plant. Loamy fertile, weed free land having proper drainage facility should be preferred. A soil mix of 70% soil, 20% compost or vermicompost and 10 % husk or sand is ideal. Selected land for nursery raising should be covered with plastic sheets or banana leaves to prevent root penetration into the lower soil layer. The appropriate time of sowing nursery for early duration varieties is from 10th to 25th June and for late duration varieties, it is 25th May to 10th June. Long and narrow nursery beds (1 m x 10 m) are more ideal. Prepare raise bed to facilitate drainage of excess water and irrigate the nursery uniformly. Prepare 80-100 plots of 1.0m x 10.0m (10sqm) with 10.16 cm height to raise nursery. Use 100kg nitrogen and 50kg phosphorus per plot in nursery. Nursery in 800-1000 square meter area is enough for transplanting in 1 hectare land. Before sowing seeds into nursery, these should be soaked in water for 24 hours and then drain and keep for another 24 hours till emergence radicles. Sow seeds in rows, 1-2 seeds per cell or hole are sufficient at dept of 1 cm. After it, cover sown seeds with a thin layer of soil. Use straw or grass to cover the beds to conserve moisture and maintain warmer temperature for germination. Spray tricoderma within 10 days after sowing of nursery. To control whitening, use 4 kg ferrous sulphates with 20 kg urea per hectare. Use 500gm Carbendazim 50% WP per hectare to control paddy blast. Use 2 kg zinc manganese carbamate per hectare to control brown spot disease. To protect the crop from various insect- pests, spray 1litre Fenitrothion 50 EC or 1.25-liter Quinolphos 25 EC or 1.5 liter Chlorpyriphos 20 EC per hectare.

Modern released varieties of rice:

Development of modern released varieties and availability of quality seeds of these released varieties had milestone in green revolution of India. Today our country not only become self-sufficient in food production but also exporting to other countries. India also has tremendous role in world food security by exporting rice in share of 40 % of world level in 2022 (Nayak *et al*., 2024). Due to systematic efforts of breeders, so far, many varieties, superior in different traits has been released.

They are developed for upland conditions as well as for lowland condition. The varieties are also developed for Boro ecosystem and aerobic situation. Upland rice production means to growing rice varieties in dry (dry environment), well drained environments and unmanaged fields. The varieties which are developed for such conditions have drought resilience characteristics and are adaptable to poor soil conditions. The field of these varieties are not flooded or irrigated. These varieties play a crucial role in providing stable yields and contribution in food security in regions with limited water by expanding area for cultivation of rice. Upland rice varieties primarily depend on rainfall and minimal irrigation. These are cultivated in areas with higher altitudes, sloping or undulating terrain and soil with less water holding capacity. Lowland rice production means growing of rice varieties in flooded condition or irrigated condition. These varieties thrive well in flooded paddy fields. In other word, these varieties are grown in standing water. Aerobic rice varieties are those varieties which are suitable under non-flooded conditions. These are thrived in well drained, aerobic soil, allowing for better water use efficiency

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and improved soil health. Boro ecosystem rice or Boro rice is a specific type of rice varieties which are grown during the Boro season, which is a major cropping season in South Asia, particularly in Bangladesh and parts of India. Boro rice is typically sown in late November to early January and harvested from April to June. The growing season have combination of both the dry winter and early summer. It thrives in cooler temperatures during the initial growing phase and warmer temperatures as it matures. The crop is usually grown in areas with sufficient irrigation so, this season does not rely on monsoon rains. Boro rice varieties prefer well drained, fertile soils. This are grown in low lying areas where irrigation can be easily managed. Boro rice varieties require a consistent supply of irrigation water. This make them more suited to regions where controlled irrigation is available. List of some prominent varieties are given in Table1.

Table 1: List of rice varieties

S. No.	Name of variety	Maturity Duration (in Days)	Average Grain Yield	Recommended for cultivation in areas	Condition
1.	CR Dhan 314	130	66.20 Q/ha	Irrigated condition of Odisha and Bihar	Lowland
2.	CR Dhan 323 (Jyotsna)	135-140	55-60 Q/ha	Odisha	Lowland
3.	CR Dhan 326 (Panchatava)	135-140	62 Q/ha	Odisha	Lowland
4.	CR Dhan 327 (Madhumita)	135-140	55-60 Q/ha	Odisha	Lowland
5.	CR Dhan 328 (Divya)	143	67 Q/ha	Odisha	Lowland
6.	CR Dhan 329	125-132	55-62 Q./ha	Odisha, Gujarat, Maharashtra and Bihar.	Lowland
7.	CR Dhan 337	118-121	50-80 Q./ha	Irrigated early transplanted condition of Odisha, Bihar, Jharkhand and West Bengal.	Lowland
8.	Pusa Basmati 1886	143	40 Q./ha	Haryana and Rajasthan	Lowland
9.	Pusa Basmati 1885	140	42 Q./ha	Delhi, Punjab and Haryana	Lowland
10.	Pusa Basmati 1847	120	50-51 Q./ha	Delhi, Punjab and Western U.P.	Lowland
11.	Pusa Basmati 1718	136-138	49 Q./ha	Delhi, Punjab and Haryana	Lowland
12.	Pusa Basmati 1637	130	38 Q./ha	Delhi, Uttarakhand, Punjab and Haryana	Lowland
13.	Pusa Basmati 1609	115-120	41 Q./ha	U.P., Delhi, Uttarakhand and Punjab	Lowland
14.	Pusa Basmati 1509	115	45 Q./ha	Punjab, Haryana, Delhi, Western U.P., Uttarakhand and Jammu & Kashmir	Lowland
15.	Pusa Basmati 1728	140-145	49-59 Q./ha	Punjab, Haryana, Delhi, Uttarakhand and Western U.P.	Lowland
16.	Pusa RH10	110-115	63 Q./ha	Haryana, Delhi and Uttarakhand	Lowland
17.	Pusa Basmati 1121 (Pusa Sugandh 4)	145	45 Q./ha	Punjab, Western Uttar Pradesh, Haryana, Delhi, Uttarakhand and Jammu and Kashmir	Lowland
18.	DRR Dhan 73	120-125	40-60 Q./ha	Karnataka, Odisha and Telangana	Lowland
19.	CSR101	125-130	39.33 Q./ha	Uttar Pradesh, Haryana, Tamil Nadu and Karnataka	Lowland
20.	DRR Dhan 74	130-135	40-70 Q./ha	Karnataka, Maharashtra, Telangana, Jharkhand and regions with phosphorus deficit soil of India	Lowland
21.	DRR Dhan 78	120-125	40-58 Q./ha	Tamil Nadu Telangana, Andra Pradesh and Puduchery	Lowland
22.	KKL4	120-125	38-56 Q./ha	Karnataka, Maharashtra, Telangana, Jharkhand and	Lowland
23.	CR Dhan 211	114-118	45-55 Q./ha	Odisha, Bihar, Jharkhand, Maharashtra, Gujarat, Tripura, Chhattisgarh and Haryana and West Bengal.	Aerobic condition
24.	CR Dhan 212	110-113	44-57 Q./ha	Odisha, Bihar, Jharkhand.	Aerobic condition
25.	CR Dhan 214	110	44.51 Q./ha	Odisha, Bihar, Jharkhand.	Aerobic condition
26.	DRR Dhan 53	130-135	49-50 Q./ha	Andra Pradesh, Telangana, Chhasttisgarh, Karnataka, Tamil Nadu, Jharkhand, Odisha, Bihar, Gujarat and Maharastra.	Aerobic condition
27.	Swarna Purvi Dhan 5	110-115	43.69 Q./ha	Bihar, West Bengal and Jharkhand	Aerobic drought condition
28.	CR Dhan 103 (Pramod)	95-100	33.96 Q./ha	Directed seeded variety of Jharkhand.	Upland condition
29.	CR Dhan 107 (Unnat Vandana)	90-95	33.70 Q./ha	Directed seeded variety of Jharkhand	Upland condition
30.	CR Dhan 108	110-114	34.46 Q./ha	Early directed seeded variety of Odisha and Bihar	Upland condition

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Genetic Gold: Why Crop Diversity is Key to Feeding the World

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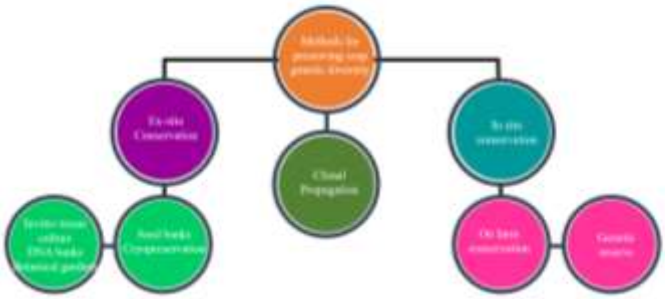
Genetic diversity refers to the variety of genes within a species. This is fundamental to food security in crops because it underpins the adaptability, resilience, and productivity of agricultural systems. Diverse genetic resources allow breeders and farmers to develop and cultivate crop varieties that can withstand changing climates, new pests and diseases, and shifting environmental conditions. This adaptability is crucial as global challenges such as climate change, land degradation, and population growth intensify. Many traditional and indigenous crop varieties, often grown by smallholder farmers, hold unique traits like salinity resistance or heat tolerance. Likewise, wild relatives of crop, those scrappy versions that grow in the wild, are genetic goldmines. Preserving them in seed banks and in the fields (called in situ conservation) is essential. But many of these genetic resources are disappearing fast due to urbanization, habitat loss, and a shift toward industrial farming.

Most Effective Methods for Preserving Crop Genetic Diversity



1. Ex Situ Conservation

- **Seed Banks:** These are the most efficient and widely used methods for preserving crop diversity. They store seeds of various crops, especially those with orthodox seeds that can withstand drying and freezing, under controlled conditions, ensuring long-term viability. Major crops like rice, wheat, maize, and barley are well represented in global seed banks.
- **Cryopreservation:** This technique involves storing plant tissues (such as meristems or shoot tips) at ultra-low temperatures (−196°C) in

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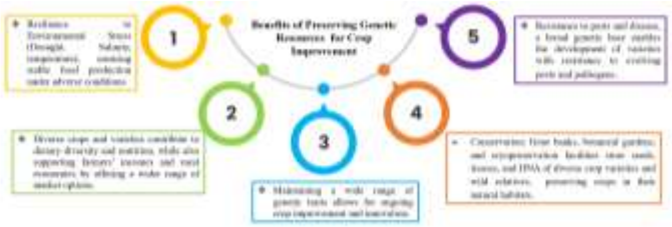
- liquid nitrogen. It is especially valuable for crops with recalcitrant seeds (those that cannot survive drying or freezing) and vegetatively propagated species like potato and banana. Cryopreservation ensures genetic stability and long-term preservation without frequent maintenance.
- **In Vitro Tissue Culture:** Plant tissues are maintained on artificial nutrient media under sterile conditions. This method is particularly effective for species with limited seed production or for vegetatively propagated crops. It allows for mass multiplication and reduces the risk of genetic erosion.
- **DNA Banks:** These involve storing genetic material (DNA or RNA) for future research and potential breeding applications. While plants cannot be regenerated directly from DNA, these banks provide a crucial backup for genetic information and support advanced biotechnological research.
- **Botanical Gardens:** These play a supplementary role by maintaining living collections of diverse plant species, including rare and endangered crops.

2. In Situ Conservation

- **On-Farm Conservation:** This strategy involves preserving traditional crop varieties (landraces) within farmers' fields. It allows crops to continue evolving under natural and human selection, maintaining dynamic genetic diversity. Farmers play a key role by selecting and cultivating diverse varieties adapted to local conditions.
- **Genetic Reserve Conservation:** Wild relatives of crops are conserved in their natural habitats, such as forest reserves or protected areas. This approach supports the ongoing evolution and adaptation of plant species, preserving alleles that may be critical for future breeding efforts.

3. Clonal Propagation

- **Vegetative Propagation:** Techniques such as cuttings, grafting, and tissue culture are used to preserve the genetic makeup of plants that do not reproduce true-to-type from seeds. This is essential for maintaining valuable traits in crops like potato, banana, and many fruit trees.



Current Threats to Genetic Diversity

Since the early 20th century, the adoption of high-yielding, uniform crop varieties and the expansion of monocultures have led to a dramatic loss of traditional varieties and wild relatives. The FAO estimates that about 75% of plant genetic diversity in agriculture has been lost since 1900. This erosion limits our ability to respond to future challenges and increases vulnerability to crop failures. Preserving crop genetic diversity is vital for developing resilient, productive, and nutritious food systems capable of withstanding future challenges. Conservation efforts- both in gene banks and in farmers' fields- are crucial investments in global food security.

Global Efforts to Save Seeds

Organizations like the Svalbard Global Seed Vault in Norway and national gene banks across the world are safeguarding crop diversity. But preservation is not just about storing seeds; it's about keeping them alive and relevant. That means involving farmers, especially indigenous communities, in conservation and sustainable use.

- Support agricultural biodiversity: Buy from local markets, encourage heirloom and traditional crop varieties.
- Advocate for policies that protect seed sovereignty and support research into crop diversity.
- Educate others about the importance of seed saving and the hidden value in traditional crops.

Preserving crop genetic diversity is not just a job for scientists or farmers, it's a global priority. Our food, our health, and our future depend on it.

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Precision Farming for Sustainable Jhum Cultivation in North East Hilly India

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Precision farming in Jhum cultivation, a traditional agricultural practice in hilly or forested regions of Northeast India, involves using advanced techniques to optimize yield and sustainability. This involves using soil sensors to measure soil moisture, temperature, pH, and nutrient levels, and using drones or GPS-based systems to create detailed maps of soil fertility. Remote sensing and drones can monitor crop health, detect issues early, and track deforestation. Regular aerial surveys can maintain a balance between agricultural land and forest cover. Precision irrigation systems, rainwater harvesting, and mulching can be integrated to ensure crops receive the right amount of water, reduce water waste, and increase yield. Precision seeding and diversification can also be used to improve crop establishment and yields. Data-driven decision-making using farm management software and predictive analytics can help farmers make informed decisions about planting times, fertilizer applications, and pest control. By reducing slash-and-burn practices, precision farming can help preserve the local ecosystem and reduce deforestation, allowing farmers to cultivate smaller, more productive plots with less intervention.

Precision farming in Jhum cultivation refers to applying advanced farming techniques to optimize the yield and sustainability. Jhum cultivation, also known as shifting cultivation, is a traditional agricultural practice primarily practiced in hilly or forested regions of Asia, including Northeast India, parts of Southeast Asia, and some areas of Africa. It involves clearing a patch of forest, cultivating it for a few years, and then moving to a new area while allowing the previously used land to regenerate and then used for growing crops like rice, maize, or millet. This method can degrade the environment over time, but incorporating precision farming

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techniques could help minimize its negative impacts while improving productivity.

Integrating Precision Farming into Jhum Cultivation:

1. Soil Health Monitoring:

Soil Sensors: These sensors can measure soil moisture, temperature, pH, and nutrient levels. By understanding the soil's condition, farmers can apply fertilizers or amend the soil as needed, rather than relying on a blanket approach, which can reduce waste and increase crop yield.

Soil Mapping: Using drones or GPS-based systems, farmers can create detailed maps of soil fertility across their land. This allows for more precise land preparation and planting.

2. Remote Sensing and Drones:

Drones and Satellite Imaging: Drones equipped with multispectral cameras can monitor crop health by detecting issues like pest infestations or water stress early. This allows farmers to target areas that need attention, rather than treating the entire field, which is more efficient and environmentally friendly.

Aerial Surveys: Regular aerial surveys can track deforestation and the effects of shifting cultivation, helping farmers maintain a balance between agricultural land and forest cover.

3. Water Management:

Irrigation Systems: By using weather forecasts and soil moisture data, precision irrigation can be applied to ensure that crops receive just the right amount of water, reducing water waste and increasing yield.

Rainwater Harvesting: In areas prone to dry spells, rainwater harvesting systems can be integrated with precision farming systems to store and optimize water usage during planting and growth periods.

Mulching: Integrating mulching with precision farming allows for targeted application using GPS and remote sensing to identify areas most vulnerable to moisture loss and erosion. Application of mulching according to the topography can make the whole process more sustainable. It not only improves the soil health but also reduce erosion in a certain level during farming and extending the productive life of a plot.

4. Crop Variety and Rotation:

Precision Seeding: Precision planters can be used to plant seeds at optimal depths and distances, which can lead to better crop establishment and yields.

Diversification and Rotation: Precision farming can help farmers choose the best crop varieties suited to their land's specific needs and ensure crop rotation strategies are effective, helping to reduce soil depletion and increase biodiversity.

5. Data-Driven Decision Making:

Farm Management Software: Farmers can use data collected from sensors, drones, and soil analysis to make informed decisions about planting times, fertilizer applications, and pest control. This can be crucial for managing the transition from traditional methods to more sustainable and efficient ones.

Predictive Analytics: By analyzing historical data on weather patterns, pest outbreaks, and crop performance, farmers can predict and prepare for future challenges, reducing the risk of crop failure.

6. Sustainable Practices:

Reducing Slash-and-Burn: By using precision farming to monitor and manage land use more effectively, the need for slash-and-burn practices can be reduced, helping to preserve the local ecosystem and reduce deforestation. Instead of clearing large areas, farmers could cultivate smaller, more productive plots that require less intervention.

Potential Benefits:

- Increased crop yields
- Efficient use of resources (water, fertilizers, pesticides)
- Reduced environmental degradation
- Improved food security

Challenges:

- **Access to Technology:** Limited access to GPS devices, sensors, or drones in remote areas.
- **Cost:** High initial investment for precision farming tools might be prohibitive.

- **Knowledge Gaps:** Farmers might require training to effectively use new technologies.

Measures to Overcome Challenges:

- **Farmer Groups/Cooperatives:** Farmers can form registered groups or cooperatives to collectively access and share agricultural technologies and tools at a reduced cost.
- **Training and Awareness Programs:** Government and NGOs can provide regular training through local extension organization to educate farmers about the benefits and usage of modern farming tools.
- **Subsidies and Financial Support:** Introducing subsidies or low-interest loans for purchasing equipment can reduce the financial burden.
- **Mobile-Based Advisory Services**: Integrating information and communication technology (ICT) solutions—such as mobile applications, SMS-based alerts, and helplines—can provide real-time, location-specific agricultural advice in regional languages. This can bridge existing knowledge gaps and support informed decision-making among farmers.

By integrating precision techniques into jhum cultivation, farmers can improve their yield, reduce environmental degradation, and move towards a more sustainable and efficient way of farming that blends traditional practices with modern technology.

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Underutilized Vegetables: The Untapped Goldmine for Pharma Industry Growth and Farmer Livelihoods

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By 2050, there will be nine billion people on the earth, and agriculture will face mounting pressure to produce more food, feed, and biofuel on a finite amount of land (Godfray *et al.*, 2010). It's predicted that in order to accommodate an estimated 40% hike in the world's population by 2050, agricultural production will need to rise by 70%. abundant-quality, nutrient-dense foods that are abundant in calories, protein, and antioxidants are usually more important in the modern period to fight against age-related illnesses like cancer and the problem of malnutrition. Underutilized crops are "minor crops" that are currently grown but these are underutilized locally or internationally due to their still low market value and worldwide production. These crops provide vital nutritional and therapeutic components that are frequently absent from staple crops. The pharmaceutical industry separates and uses these therapeutic and nutritional ingredients to create cancer medications. A significant source of food and money, particularly for underemployed and impoverished farmers, is the exploitation of these underutilized wild resources. By better using the nutritional and medicinal qualities of underutilized vegetables, this rising need can be satisfied. Minor grains, root and tuber crops, vegetables, pulses, fruits and non-timber forest products are examples of underutilized food sources that could greatly improve food and nutritional security, guard against internal as well as external market disruptions and climatic uncertainties and enhance ecosystem functions and services, all of which would increase sustainability. When compared to global vegetables like cabbage and tomatoes, many traditional or indigenous vegetables have a higher nutritional value (Keatinge *et al.*, 2011). A significant contribution to achieving nutritional security may be made by conventional vegetables and underutilized legume crops, which are providers of vital vitamins, minerals, protein, and other phytonutrients.

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A wider use of underutilized and neglected crops and species, either as stand-alone crops or interplanted with main staples in cereal-based systems, would offer multiple options to build spatial and temporal heterogeneity into uniform cropping systems, ultimately leading to a more sustainable supply of diverse and nutritious food. Traditional underutilized vegetables with commercial, medicinal, and cultural value include Africal night shade (*Solanum scabrum*) Amarnath (*Amaranthus* Spp.) water spinach (*Ipomoea aquatica*) Asian (*Solanum melogena*) and drumstick (*Moringa oleifera*), Malabar spinach (*Basella alba*), winged beans (*psophocarpus tetragonolobus*), and many gourd species. Many of these crops may be cultivated with little help from outside sources, are hardy, and are suited to certain marginal soil and climate conditions (Hughes *et al.*, 2013). In Southeast Asia and Eastern Africa, several indigenous vegetables are gradually making their way from the underutilized category into the commercial mainstream and are becoming a more appealing food group for the wealthier sectors of the population.

Medicinal and Nutritional values of underutilized vegetables

Amarnathus

Amaranth is an annual or short-lived perennial plant that grows in warm and humid climates all over the world. According to reports, amaranthus leaves have a dry weight protein content of 17.5% to 18.3%, of which 5% is lysine which is an essential amino acid that is absent from most diets that rely on tubers and cereals. It has been observed that the dry weight basis of the protein levels in the leaves of *Amaranthus blitum* is 27%, that of *Amaranthus caudatus* is 30%, that of *Amaranthus hybridus* is 28% and that of *Amaranthus tricolor* is 33%. According to reports, cooked leaves that aren't combined with other foods comprise 4% carbs and 8% protein. According to Shukla *et al.* (2010), amaranthus is a cheap, high-protein, high-dietary-fiber food. A significant supply of vitamins, particularly pro-vitamin A, which is lacking in the tropics and causes blindness in thousands of children annually, is also found in vegetable amaranth. Vitamins C, K, and folate are all abundant in the leaves. Compared to spinach, amaranthus species have three times the amounts of vitamin C, iron, niacin and calcium. Compared to lettuce, it has seven times more iron, twenty times more calcium, and eighteen times more vitamin A. Along with isothiocyanates and phytochemicals like phenolic compounds, which have potent antioxidant qualities, amaranthus leaves also contain significant concentrations of carotene and minerals including sodium, copper, manganese, and chloride. It has been observed to help in the suppression and prevention of diseases such as arteriosclerosis, ageing and cancer.

Pointed Gourd (*Trichosanthes dioica*)

Pointed gourd is a prominent crop belongs to Cucurbitaceae family that is widely grown in river bottoms of Bihar, West Bengal and Uttar Pradesh in India. The pointed gourd is renowned as the "King of gourds" due to its high nutritional content and medicinal potential. According to Nadkarni *et al.* (1996), the juice of its leaves is used as a febrifuge and tonic for edema, subacute and alopecia, liver enlargement. Plant leaves are used in Ayurveda as laxatives, diuretics, cardiotonics, antipyretics, and antiulcers. Vitamins A, C, tannins, saponins, alkaloid compounds, proteins, tetra and pentacylic triterpenes, The combination of noval peptides, and other chemical components are all present in *T. dioca* (Nitin Kumar *et al.*, 2012).

Gherkin (*Cucumis sativus* var. *anguria*)

Gherkin is a type of cucumber that contains practically all of the nutrients found in a cucumber. It has an average number of fats and calories, which aids in weight maintenance and lowers the risk of major conditions like as cancer and heart disease. It promotes the absorption of essential nutrients such as folate, calcium, iron and vitamin A. One large sweet gherkin has 114 micrograms of beta-carotene. A small sweet gherkin contains 7.1 micrograms vitamin K, which accounts for 8% of the 90 micrograms of vitamin K required by women and 6% of the 120 micrograms required by men. A medium gherkin

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contains 12 milligrams of vitamin K, while a large sweet gherkin contains 16.5 micrograms.

IVY Gourd (*Coccinia grandis*)

The ivy gourd is called as kundru in hindi. Fruits are high in lycopene (5.68 mg $100g^{-1}$) and β-carotene (2.24 mg 100 g^{-1}), whereas leaves provide protein (3.3-4.9 g) and vitamin A (8000-18000 IU). The fruits are anti-diabetic and have antioxidant properties. In Ayurveda, it is used to treat skin eruptions, tongue sores, and earaches.

Sweet Gourd (*Momordica cochinchinensis*)

Sweet gourd belongs to the Cucurbitaceae family and has appetizing soft fruits and young leaves. The fruits are rich in vitamin A, C and protein. The fruit as well as leaves have therapeutic characteristics that can treat ulcerations, bone fractures and lumbago. Bessisterol and Saponin are abundant in the roots and can be employed in the pharmaceutical industry. Seeds can be used to treat edema, ulcers and abscesses.

Karchikai (*M. cymbalaria*)

Karchikai has excellent nutraceutical properties and is utilized as a vegetable. This perennial climber, which grows in the South Indian states of Andhra Pradesh, Tamilnadu, Maharashtra, Karnatka and Madhya Pradesh, is only accessible during the Rabi and Kharif seasons. Originally regarded as a weed and this crop is now cultivated as a vegetable because of the therapeutic benefits of its tubers. It is possible to use leaves as a leafy vegetable in addition to fruits (Kirtikar & Bashu, 1989). Because of the poor quality of the planting material, it is not grown economically. Iron, calcium, beta-carotene, fiber, and vitamin C are all abundant in it. It has antidiarrheic, antidiabetic, hepatoprotective, antiallergic, nephroprotective and antimicrobial qualities, among other therapeutic benefits. Compared to bitter gourd, Karchikai has three times the calcium concentration. Additionally, the potassium concentration is double of bitter gourd (Gopalan *et al.*, 1994). Because they contain flavonoids, steroids, tri-terpenes, and saponins, this crop's tubers, leaves, and fruits are also used medicinally. triterpenes, Sterols, saponins and cardiac glycosides are all found in tubers. This crop can be utilized as a weapon to combat hunger and malnutrition.

Basella (*Basella Alba, Basella rubra*)

Vine spinach, or *Basella Alba*, is a popular leafy green vegetable of tropical region that is grown as a backyard herb in kichen gardens. It is a member of the basellaceae family and comes in two main cultivars: *Basella Alba*, which has a deep green leaves and green stem while *Basella rubra*, which have a dark green and purplish stem foliage with pink veins. Kumar *et al.* (2013) noted that Basella Alba has high levels of calcium, magnesium, iron, and other essential antioxidants. The plant contains several minerals, vitamins and a trace quantity of soluble oxalates as well as essential amino acids such as iso-leucine, arginine, leucine, lysine, tryptophan and threonine. Basella alba contains anti-inflammatory, anti-microbial, anti-cancer, antiviral, central nervous system depressant, haepatoprotective, and having wound-healing properties due to the presence of lupeol and B-sitosterol (Gupta *et al.*, 2008).

Elephant foot yam (*Amorphophallus campanulatus)*

The underrated aroid *Amorphophallus campanulatus* commonly referred to as "Jimikand" or "Elephant foot yam," belongs to the family Araceae. In the Ayurvedic medical system, this thick, tuberous native herb is used to treat a number of human ailments. The corms are pungent, acrid, and dry; they improve taste and appetite; they are aphrodisiac, digestive, and antihelmintic; they help with elephantiasis, inflammations, hemorrhoids, hemorrhages, dysentery, splenopathy, amenorrhea, seminal weakness, exhaustion, anemia, and general debility. To treat acute rheumatoid arthritis, fresh corms are used externally as an irritant. This pickle-like substance is a heated carminative. It contains lupeol, triacotane, stigmasterol, β-sitisterol, β-sitosterol palmitate and betulinic acid, (Ramalingam *et al.*, 2010). The corms are known to have

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antifungal, antibacterial and cytotoxic activities due to the presence of amblyone (triterpene) and diterpenoid termed salviasperanol (Anonymous 1985). Corm extracts in ethanol, water exhibited antioxidant and hepatoprotective effects (CCl_4-induced liver damage). Asthma, rheumatism, cancers, gastrointestinal disorders, piles, and spleen enlargement have all been treated using the plant's blood-purifying tuberous roots (Kirtikar and Basu, 1989).

Drumstick *(Moringa oleifera)*

The nutritional and therapeutic benefits of *Moringa oleifera*, a fantastic multipurpose tropical tree, are often overlooked. People have been consuming Moringa in a variety of ways for over a century. For months, moringa leaves retain most of their nutritious content whether they are eaten fresh, roasted, or dried. According to epidemiological research, *Moringa oleifera* leaves contain anti-inflammatory, ulcer-, anti-atherosclerotic, and anticonvulsant properties in addition to being a rich source of nutrients (Dahiru *et al*., 2006). Skin infections, anxiety, anemia, blackheads, asthma, blood impurities, catarrh, bronchitis, chest congestion, cholera, and other illnesses have all been treated with moringa for ages in a variety of cultures (Singh *et al*., 2012).

In addition, *Moringa oleifera* contains hepatoprotective, antipyretic, cholesterol-lowering, renal, diuretic, antidiabetic, anti-inflammatory, antihypertensive, anti-spasmodic, antitumor, antioxidant, anti-epileptic and antiulcer, qualities. Additionally, it was found that moringa oil has been used in skin ointments since ancient Egypt.

Winged bean (*Psophocarpus tetragonolobus)*

The tropical legume *Psophocarpus tetragonolobus* (L.), commonly referred to as the Goa bean or winged bean, is widely distributed in hot, humid equatorial countries including Thailand, the Philippines, India, Burma, and Sri Lanka. Because of its high protein content, which makes it a multipurpose legume, it is frequently referred to as a miracle bean (Peyachoknagul, 1989). An underutilized plant that has the potential to grow into a significant multipurpose food crop is the winged bean. You can eat the entire plant of winged bean. You can eat the flowers, leaves, roots, and bean pods cooked or raw; the pods are edible even if they are not ripe or cooked. You can eat cooked seeds. Among other minerals, each of these elements offers calcium, iron, vitamins A, and C. It is advisable to consume the sensitive pods, which are the plant's most popular part, before they get to be 2.5 cm long. Like spinach, the young leaves can be harvest and eaten as a leafy vegetable. The tuberous, nutrient-dense roots taste nutty. The protein content of winged bean roots is higher than that of many other root vegetables, at about 20%. The protein content of the leaves and flowers is considerable (10–15%). The seeds include protein around 35% and fat 18%. The high niacin content of winged beans aids in the prevention of blood clots by lowering platelet aggregation. This suggests that by controlling lipoprotein and apolipoprotein levels, the risk of cardiovascular problems associated with the illness will be reduced.

Conclusion

Underutilized vegetables hold immense potential as rich sources of medicinal and nutritional value. These crops, often neglected in commercial agriculture, offer significant benefits to both the pharmaceutical industry and farmers. Their high concentrations of essential vitamins, minerals, antioxidants, and bioactive compounds make them valuable in combating malnutrition, age-related diseases, and chronic illnesses like cancer and diabetes. Moreover, their adaptability to marginal environments provides a sustainable agricultural option for resource-limited regions. By promoting the cultivation and utilization of underutilized vegetables, pharmaceutical industries can harness their therapeutic properties for drug development, while farmers can diversify their income sources. Recognizing the importance of these crops can enhance food security, boost rural livelihoods, and contribute to the global pursuit of sustainable health and agricultural systems.

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Healing Plants For Healthy Life
Role of Indoor Plants in enchancing Oxygen levels in living Urban

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Urban apartments, often trapped in the hustle and bustle of city noise and pollution, can benefit from a secret weapon: Indoor Ornamental Plants- Decorative & absorbing potentially harmful gases and cleaning the air inside modern buildings **(NASA Scientists).** They plays an important role in environment improvement like temperature regulation, oxygen production, carbon sequestration, control urban glare and reflection and noise pollution. They purify and renew our stale air by filtering out toxins, pollutants, harmful viruses, mold spores and the carbon dioxide we exhale. Here we are going to explore the role of houseplants in improving indoor air quality by reducing air pollution levels. We also examines how plants absorb and break down harmful pollutants, such as VOCs and particulate matter, and their potential to reduce indoor air contaminants.

Sources of Indoor Pollution :

Asbestos, Lead, Volatile Organic Compounds, Combustion by-products , Biological Pollutants (Bioeffluents)**,** Household Products and Cleaning Agents, Petroleum-Based Products, Building Materials and Furniture are few sources of indoor pollution. Studies show indoor air can be 2 to 50 times more polluted than outdoor air. Indoor pollutants typically come from building materials, human activities, and outdoor air entering the building . This problem has worsened in newer, energy-efficient buildings with lower ventilation rates.

Mechanism involved in purification of air by Indoor plants:

- Adsorption of gaseous contaminants and particulate (dust and bio aerosols) onto leaf

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- surfaces through stomata and accumulation in various internal structures
- Degradation of gaseous contaminants through various metabolic pathways
- Removal of CO_2 and production of O_2 through photosynthesis
- Increasing humidity levels through leaf transpiration and evaporation from rooting media
- Reducing airborne concentrations of dust and bio-aerosols

Healing Plants for air purifying:

1. **Rubber Plant (*Ficus elastica)***
It has impressive air-cleaning abilities. Studies show that it can remove toxins from indoor air, making it a great choice for homes and offices. It is excellent at filtering out formaldehyde and benzene.

2. ***Dracaena spp***
It is commonly known as snake plant. It gains its popularity in its effective air purifying properties. It purifies the polluted indoor air by removing the Volatile Organic Compounds(VOC's) such as xylene, toluene, formaldehyde etc.

3. **Snake Plant (*Sansevieria trifasciata*) – The Night time Oxygen Producer**
Also known as Mother-in-Law's Tongue, the Snake Plant is famous for doing something most plants don't, it produces oxygen at night.

4. **Gerbera Daisy (*Gerbera jamesonii*)**
It is extremely effective in removing chemical vapours such as benzene from the air. These benzene fumes are exhausted from glues, paints, solvents and art supplies.

5. **Bamboo Palm (*Chamaedorea seifrizii*)**
Its ability to absorb carbon dioxide and release oxygen contributes to a healthier environment. In addition to improving oxygen levels, bamboo palm is considered a natural air purifier.

6. ***Aloe vera***
Aloe vera is known for its aesthetic value, beauty and its medicinal properties. It removes the air borne toxins and other inorganic substances that are carcinogenic to plants.

7. **Devil's Ivy (*Epipremnum aureum)***
It has the durability and ability to filter benzene in low-maintenance environments. It is also act as natural humidifier which release moisture into the environment through transpiration process.

8. **Areca Palm (*Dypsis lutescens)***
A medium-sized Areca Palm can release nearly 1 liter of water per day into the surrounding air, making it excellent for people who suffer from dry skin, respiratory issues, or allergies.

9. **Peace Lily (*Spathiphyllum spp.)***
The roots of the peace lily also play a role in detoxifying the air. They can help break down potentially harmful gases that are absorbed by the plant.

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10. Spider Plant (*Chlorophytum comosum*)

It can readily reduce the concentration of numerous air pollutants in the indoor microenvironment and promote human wellbeing.

11. Boston Fern (*Nephrolepis exaltata*)

These ferns are proficient in removing indoor air pollutants like formaldehyde, xylene, and toluene. It reduces the Trichloroethylene concentration into 40% to 60%.

Quality Oxygen Production:

Houseplants improve indoor air quality primarily by absorbing carbon dioxide and releasing oxygen through photosynthesis. During this process, plants take in carbon dioxide (CO_2) through tiny pores on their leaves, called stomata, and absorb sunlight using chlorophyll, the green pigment in their cells. In the presence of water, which plants draw up through their roots, the energy from sunlight enables plants to convert CO_2 and water into glucose and oxygen. Oxygen is then released into the air, while the glucose is used as energy for the plant's growth and maintenance. This natural oxygen production helps create a healthier, more comfortable environment for occupants by boosting indoor oxygen levels. Higher oxygen indoors has various positive effects on human health. With increased oxygen, people may experience better concentration, improved memory, and reduced mental fatigue, leading to heightened focus and alertness throughout the day.

In conclusion, indoor plants are an effective and sustainable way to improve indoor air quality. By absorbing harmful toxins and releasing oxygen, these plants act as natural air purifiers, promoting a healthier and more comfortable living environment. With indoor air pollution becoming an increasingly common concern, incorporating indoor plants into your home or office space offers a simple yet effective solution. These plants not only enhance the aesthetic of the room but also contribute significantly to reducing pollutants like formaldehyde, benzene, and trichloroethylene.

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Crop Evapotranspiration-Based Irrigation Strategy for India

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The actual test of the farming sector is being able to feed the global population increasingly rising with each passage of time and attempt to reduce the utilization of water within the sector. The population of the world counted nearly 7.6 billion till mid-2017 and it is to further grow in the next years slightly more than a billion people with that number expected to reach 8.6 billion as of 2030 and grow further on to 9.8 billion 2050 (UN-Population Division, 2017). Therefore, the demand for food will increase by 60% within the same period (Alexandratos and Bruinsma, 2012). Agriculture uses approximately 70% of total freshwater withdrawals worldwide and more than 90% in the least developed countries (FAO, 2011). Absent increased efficiency measures, agricultural water use will grow by approximately 20% globally by 2050 (WWAP, 2012) or forecasts the world may experience a 40% global water deficit by 2030 under business-as-usual (2030 WRG, 2009). Global agriculture has consumed around 2,600 km3 of water per year since the year 2000, i.e. 2% of annual precipitation over land and 17 mm of water evenly distributed over the global land area. This is a +75% increase since 1960 and a +400% increase since 1900 levels of irrigation. 18% of the world's cropland, i.e. approximately 2% of the entire land surface are irrigated and yield 40% of global food. On average, irrigated areas get an addition of 800 mm of water per year. (Sacks et al., 2009).

Crop evapotranspiration (ETc) is a crucial hydrological, environmental, and agricultural study parameter and has a central position in irrigation project designing and managing and water management in irrigated and rainfed agriculture. ETc is measured directly using lysimeters and Eddy covariance systems, but it is also estimated by the indirect method through reference crop evapotranspiration (ETo) and crop coefficients. (Jensen et al. 1968).

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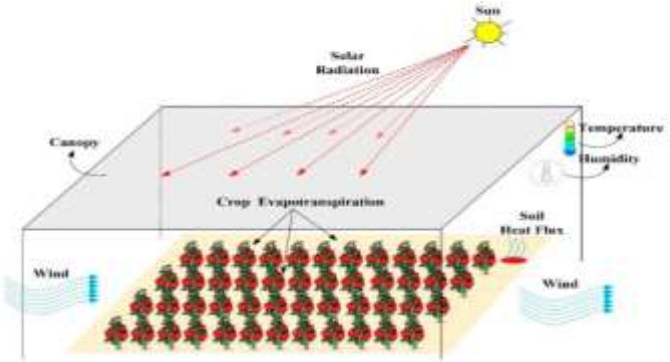


Fig.1. Schematic diagram of climatic conditions and their impact on crop evapotranspiration (ETc) Source: https://www.mdpi.com/2073-4395/9/6/334

It was the pioneer relating crop actual evapotranspiration to the reference evapotranspiration using the conversion factor called crop coefficient (Kc). Kc is crop-specific and growth-stage specific and because of the combined interactions of crop factors, soil water status and type of soil, crop practices management, canopy and aerodynamic resistance, climatic conditions like the available energy, adjacent air vapor content in the vapor, air vapor deficit, etc (Manneh et al.2017). The various ETo estimation methods can be classified as empirical formulations of radiation (Priestley-Taylor (P-T)), temperature (SCS Blaney-Criddle, Hargreaves Samani (H-S)), combination theory types (Penman Monteith, FAO-24 Penman (c ¼ 1), FAO-24 corrected Penman) and pan evaporation (FAO-24 pan). Reference crop evapotranspiration estimation has monumental significance in the determination of crop water demand and irrigation scheduling (Rasul 1992). This paper is to discuss the scientific foundations and practical benefits of the way crop evapotranspiration, and evaporation, Transpiration, and soil stabilization, based on empirical evidence and actual case studies. To the best of our knowledge, this is the first protocol considering the climate conditions. Furthermore, citrus is economically valuable for farmers, thus the provided protocol will add value to this farming activity.

Crop evapotranspiration (ETc):

Crop evapotranspiration is defined as the amount of water lost through evaporation from the soil surface and transpiration from the crop under specific conditions. These conditions include a well fertilized disease-free crop growing in reasonably large plots with adequate moisture in the soil, optimum climatic conditions, yielding maximum production. Crop evapotranspiration is the amount of water that is lost through evapotranspiration.

Evapotranspiration (ET):

Evapotranspiration denotes the quantity of water transpired by plants and the moisture evaporates from the surface of the soil and vegetation. The essential requirements in the evaporation process are the

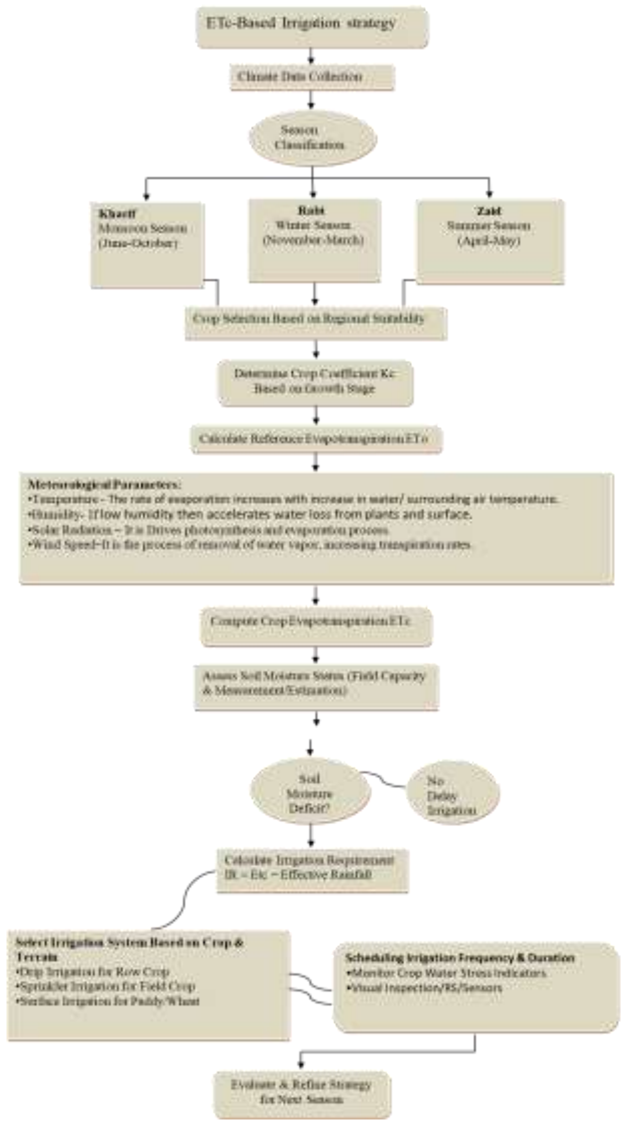
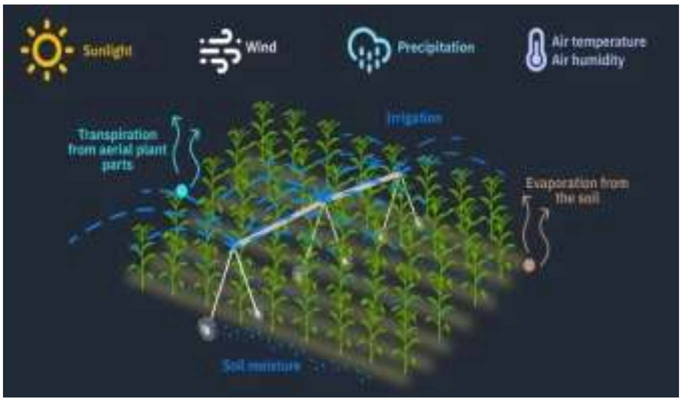


Fig.2. A simple way towards crop evapotranspiration-based irrigation strategy

sources of heat to vaporise the liquid water and the presence of a gradient of concentration of water vapour between the evaporating surface and surrounding air. Evaporation energy may be solar energy the air blowing over the surface.

Transpiration:

Transpiration is the process by which water vapour leaves the living plant and body and enters the atmosphere. During the growing period of a crop there is a continuous movement of water from the soil into the roots through the stem and out through the leaves to the atmosphere.



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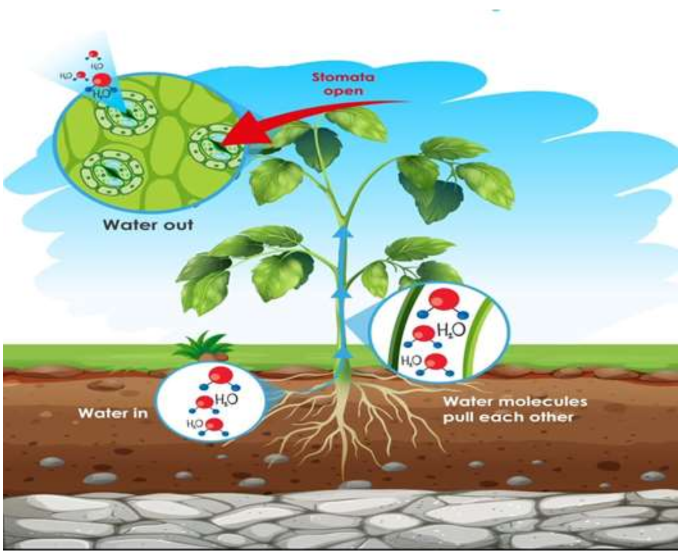

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Fig.3. (a, b) Schematic diagram of Process of evapotranspiration and transpiration
Sources:https://greenstories.co.in/evapotranspiration-process-and-methods/, https://infinitylearn.com/surge/articles/transpiration/

Begin: Irrigation planning

A strategy must always precede the planning as this is required for ensuring proper efficiency in water usage and improvement in figure output levels. There is a need to study climatic patterns, evaporation, transpiration, evapotranspiration and soils as well as the crops being grown to prepare the necessary plan in providing the water during the growth stages and not waste it.

Climate Data Collection

The primary activity in planning for the irrigation of land is the thorough gathering of climatic data. Every country has its own national agency for systematic collection, storage and retrieval of weather data. The Indian Meteorological Department, Pune is the repository of weather data in India. Commencing 1984, the FAO of the United Nations has published mean monthly agro-climatic data from 2300 stations under FAO Plant Production and Protection Series. There are separate volumes for different countries.

Determine Crop Coefficient Kc Based on Growth Stage

The values of crop coefficient Kc vary greatly with the stage of growth of the crop, as the crop develops the ground cover, crop height and leaf area change. The growing period of crops can be divided into four distinct stages: (i) initial stage, (ii) crop development stage, (iii) mid-season stage, and (iv) late season stage. The length of growth periods varies with the crop and its variety, the planting date, and climate.

Calculate Reference Evapotranspiration ETo

It is the evapotranspiration rate from a reference surface. The FAO Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements (1990) adopted the following definition for the reference surface: "a hypothetical surface of grass with specific characteristics, including height, actively growing conditions, ground coverage, and simple water supply". calculated using the FAO Penman-Monteith equation

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Compute Crop Evapotranspiration Etc

All the methods of calculating crop evapotranspiration involve the following relationship:

$$ETc = Kc \times ETo$$

Where,

ETc = Evapotranspiration of a specific crop (mm/day)

Kc = Crop coefficient (dimensionless)

ETo = Potential evapotranspiration (or reference crop evapotranspiration) (mm/day)

Assess Soil Moisture Status (Field Capacity & Measurement/Estimation)

The principal methods for direct measurement of evapotranspiration are: (i) lysimeter experiment, (ii) field experimental plots, (iii) soil moisture depletion studies, and (iv) water balance method. Its costly and time consuming. Even though direct measurements of ET are usually not possible for routine measurements, they are important for the evaluation of ET estimates obtained by indirect methods.

Calculate Irrigation Requirement (IR)

It has been indicated how the crop water need (ETc) is determined. This water can be supplied to the crops in various ways:

- Rainfall
- Irrigation
- A combination of irrigation and rainfall

Calculate the irrigation Requirement:

$$IR = Etc - \text{Effective Rainfall}$$

Where,

IR = Irrigation Requirement, and Etc = crop water need

Select Irrigation System Based on Crop & Terrain

- **Drip Irrigation for Row Crop**
  Water is applied frequently at low rates from a low pressure and delivery system comprising of small diameter plastic pipes fitted with outlets, called emitters, or drippers, directly to the plant roots.
- **Sprinkler Irrigation for Field Crop**
  Sprinkler irrigation system it is the process of artificial application of water. it conveys water through pipe and supply it to all the operating sprinklers at the appropriate pressure at the nozzles of the sprinklers the pressure head is converted to velocity head. Water flows out of the nozzle in the form of a jet which breaks down into drops of water which fall on the soil surface.
- **Surface Irrigation for Paddy/Wheat**
  Surface Irrigation system water is applied directly to the soil surface from a channel located at the upper reach of the field/Land. Water may be distributed through the border strips, check basins or furrows.

Fig.4. Irrigation Systems: The Cornerstone of Water Efficiency

Scheduling Irrigation Frequency & Duration

Irrigation scheduling is the process of determining the time to irrigate and how much water is to be applied in each irrigation. Necessary for efficient use of water, energy and other production units such as fertilizers. It is decision making process.

Visual Inspection/RS/Sensors

- **Visual Inspection:** Keep an eye out for symptoms like discoloration, curling, wilting, or stunted growth in the leaves.

Monitor Crop Water Stress Indicator

Soil indicators	Plant indicators
• Appearance and feel • Gravimetric sampling • Tensiometers • Porous block • Neutron scattering	• Appearance and growth • Leaf temperature • Leaf water potential • Stomatal resistance

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- **Remote Sensing:** To ascertain water stress at a large scale, use satellite or aerial photography.
- **Sensors:** Soil moisture probes and plant sensors provide immediate information.

Evaluation & Improve Strategy for Next Season

Monitor & Optimize Strategy for Next Crop After harvest, review the result (crop growth, water use efficiency, irrigation practice) to improve and develop strategy for the next cropping season for better sustainability.

Conclusion

In India, efficient management of water is essential to sustain agricultural productivity, especially in view of increasing water scarcity and increased food demand due to population growth. To develop accurate irrigation plans that are appropriate for the soil, crops, and climate conditions of the country, this article emphasizes the important role that crop evapotranspiration (ETc) must play. The basis of a good irrigation system that can significantly enhance the efficiency of water usage while ensuring maximum yields in the crops is the combination of reference evapotranspiration (ETo), crop coefficient (Kc), and effective climatic information. Farmers and policymakers can shift towards a more sustainable agriculture system by adopting scientifically proven methods such as the FAO Penman-Monteith equation for estimating ETo and adjusting irrigation schedules based on crop stress indicators and real-time soil moisture monitoring.

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Fungal biocontrol agents of nematodes: The unexplored beneficiaries

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Nematodes are hidden enemies of agriculture that cause an approximate loss of around 120 billion dollars. Chemicals are beneficial in managing nematodes but has adverse environmental impact. So fungal biocontrol agents like *Harposporium, Hirsutella and Verticillium, Penicillium, Trichoderma, Purpureocillium* etc. that are promising biocontrol agents of nematodes can be employed for the management of the nematodes. In addition to that native strains of fungal bio control agents can be explored for easy adaptation and quick management. The fungal biocontrol agents also enhance soil fertility that will support the degrading soil quality due to chemicals.

The peaking human population of the world is less adapted for jeopardy caused by enemies of agriculture i.e. insect pest and nematodes. Plant-parasitic nematodes (PPN) are the hidden enemy of agriculture as they are microscopic and ubiquitous in nature. They are transparent organisms that are associated with all agricultural crops and causes significant threat to global food security. Collectively they decline the production by an estimated 80-118 billion dollars per year. Major genera of PPN under order Tylenchids that are considered most important agricultural pests are *Meloidogyne, Heterodera, Hoplolaimus, Pratylenchus and Rotylenchulus*. The go to management strategy for the control of nematodes are application of chemical molecules that possess quick knock down effect. The chemicals neutralize the nematodes but alongside forces undesirable disadvantages like traces of chemicals in drinking water, hostiling beneficial soil organisms and flickering sustainability. The urgent concern on overuse of fertilizers and pesticides and its adverse impact on environment has ignited researchers to reach out for safer and holistic insect pest and nematode management strategies. Bio controls an alternative to chemical molecules can be simplified as the role of predators, parasites and microorganisms in maintaining the harmful insect pest and pathogens population below economic threshold level to avoid economic loss. Considering nematodes, the options that can be exercised as biocontrol agents (BCA) are bacterial biocontrol agents, nematophagus fungus and predatory nematodes which can attribute to nematode management and also address the cause of sustainability. Fungal biological control is an exciting and rapidly developing research area and there is growing attention in the exploitation of fungi for the control of nematodes. Fungal bio control agents occupy 2% of the pesticide company and is considered as a viable option for management of nematodes due to its various advantages.

2. Fungal Bio control agents of nematodes:

2.1: Nematophagus Fungi.

Nematophagus fungi are found in most fungal taxa like Ascomycetes, Basidiomycetes, Zygomycetes, Chytridiomycetes and Oomycetes. Also known as nematophagus fungi its functions to colonize and parasitize nematodes for exploiting its nutritious substances. Cutting down the poisonous effect on humans fungal BCA are self-generating and provide continuous protection. Nematophagus fungi usually prefer organic soils however, they can reproduce in nearly all types of soil because of their few nutritional and vitamin requirements. Mainly classified as facultative and obligate parasitise of nematodes, the facultative parasites through specialized adhesive spores or by means of developing appressoria can penetrate the nematode body or eggshell. The spores breaching its cuticle germinate in nematodes digestive system or may penetrate directly into body by adhering onto its cuticle. Another mode of parasitism is the nematode trapping method when the moving stages of nematodes are trapped inside fungal hyphal rings of various shapes and sizes. Lateral branches of vegetative hyphae create non constricting rings that trap nematodes while constricting rings are the most specialized traps that swell quickly and hold the nematode tightly in its grip. Trapping fungi after its initial grip onto nematode secretes antimicrobial and nematicidal compounds like linoleic acid and pleurotin that are positively corelated with the nematode management. The nematophagus fungi are usually distributed in the upper 30 cm of the soil. Some fungi increase their trapping chances by producing attractive compounds like attracts parasitic nematodes.

2.2: Endoparasitic Fungi.

The Endo parasitic fungi (EF) are mostly cosmopolitan and the major genus of this group are *Harposporium*, *Hirsutella* and *Verticillium*. Being mostly obligate parasites, they infect broad range of nematodes and live their whole vegetative life cycle inside their infected host. The spores produced by EF are ingested by nematodes that germinate inside nematode body while some EF produces zoospores that swim towards the nematode and enters the body through its natural openings (mouth, anus, excretory pore). A penetration peg is developed from the encysted zoospore which breaches the nematode cuticle and usually invades and digests the nematode cuticle within 24 h. Then the hyphae develop some sporangium containing zoospores that can infect new nematode hosts after releasing. *Hirsutella rhossiliensis* was able to decrease nematode populations of *Meloidogyne javanica*, *Heterodera avenae*, *H. glycines* and *Criconema xenoplax*, *Heterodera* spp., *Ditylenchus destructor*, *Meloidogyne hapla*, *Pratylenchus penetrans*, *Anaplectus granulosus*, and even larvae of *Globodera rostochiensis*. Adding organic amendment to soil can indirectly increase the population densities of the fungus by stimulating bacteriophagous nematodes. One neutral serine protease and more recently a new extracellular alkaline protease (Hasp) has been described from *H. rhossiliensis*. This enzyme was purified, cloned and examined against nematodes. Hasp could kill the juveniles of the soybean-cyst nematode (*Heterodera glycines*) after purification.

2.3: Egg and Female parasitic fungi

The group of fungus are called as opportunistic fungi as upon availability they infect eggs and sedentary stages of nematodes and otherwise survive saprophytically in soil. Certain

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genus of *Purpureocillium*, *Pochonia*, *Nematophthora*, *Fusarium*, *Clindrocarpon*, *Cephalosporium*, *Trichoderma*, *Exophila*, *Phoma*, *Dactylella* etc. have been frequently found associated with the eggs, females and cysts of plant nematodes. The sedentary stage of nematodes serves as a selective substratum for fungal colonization. The parasites of egg and sedentary stages have attracted more attention because of their high potential in biological control of economically important nematodes. Mode of action explains that nematodes egg is composed of chitin and protein and the specialized penetration peg k/a appressorium penetrates the eggs. The fungi which can produce more extracellular enzymes (especially protease, chitinase and collagenase) are considered much more effective in infection of nematode eggs. Similarly, the toxin-producing fungi secretes toxin that immobilizes the nematodes before penetration of hyphae through the nematode cuticle or sends signals that act as repellents for the nematodes.

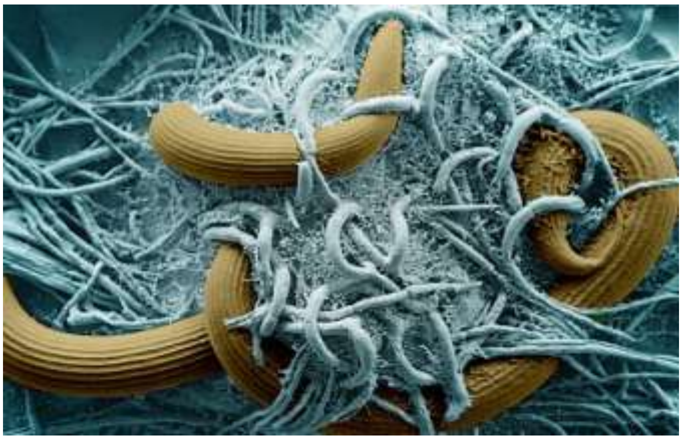

Fig 1: Fungus and their trapping structures

Fig 2: Trichoderma spp. a potential BCA

Table 1: Documentation of fungal biocontrol agents against nematodes

Sr. No.	Fungal Biocontrol agent	Nematode	Crop	Reference
1	*Trichoderma asperellum*	*Meloidogyne* spp.	Tomato	Exposito *et al.*, 2022
2	*Trichoderma viride*	*Meloidogyne graminicola* *Meloidogyne* spp.	Rice Cucumber	Patil *et al.*, 2020 Amarasinghe *et al.*, 2020
3	*Purpureocillium lilacinum*	*Meloidogyne* spp and *Rotylenchulus* spp.	Cucumber	Amarasinghe *et al.*, 2020
4	*Penicillium chrysogenum*	*Meloidogyne incognita*	Tomato Brinjal	Hussain *et al.*, 2018
5	*Pochonia chlamydosporia*	*Globodera pallida*	Potato	Sikandar *et al.*, 2020
6	*Beauveria bassiana*	*H. filipjevi*	Wheat	Vieira Dos Santos et al., 2019
7	*Verticillium leptobactrum*	*P. vulnus*	Apple	Abad et al., 2019
8	*Arthrobotrys oligospora*, *Glomus fasciculatum*	*P. zeae*	Maize	Kassam *et al.*, 2023
9	*Purpureocillium lilacinum*	*Aphelenchoides besseyi*	Rice	Zhang *et al.*, 2020
10	*Dactylellina ellipsospora* and *D. dactyloides*	*Meloidogyne spp.*	Tomato	Persson and Janson., 1999
11	*Haptocillium* spp.	*D. dipsaci*, *Globodera rostochiensis* and *Panagrellus redivivus*	Potato	Glockling and Holbrook., 2005
12	*P. chlamydosporia*	*Meloidogyne arenaria* and *Heterodera glycines*	Peanut	Morgan jones *et al.*, 1981
13	*Glomus etunicatum*	*H. glycines*	Soybean	Benedetti et al., 2021

<u>Future prospects and conclusion</u>:

The fungal biocontrol agents have various advantages like being neutral to non-target pest, environmentally sustainable, easily available etc but also possesses various disadvantages like temperature sensitive, moisture requirement, lengthy registration process and adaptation to ecology. So, in this regard research should be carried out in unearthing native potential fungal strains against the nematodes that can be easily adaptable to the ecological conditions and that is nontoxic to humans.

In-vitro results of the biocontrol agents are promising and proper planned steps should be taken to implement in in filed conditions for better outreach. Fungal biocontrol agents promise to be effective in organic soil and has improved productivity qualities. Researchers should unearth the mechanisms that are indulged in the management of the nematodes that provides a better clear outlook about biocontrol agents which is still unclear and competing to the pesticide industries, marketing and outreach activities about the benefits of the fungal biocontrol agents should be carried out by extension workers to the farmers for early adaptation and fulfilling the sustainability goals.

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Applications of Remote Sensing in Fruit Crops Management

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As originators combined their previous field knowledge with a learning- by- doing mindset and searched for useful applications for fruit crops management, a gradual elaboration of information technologies has been observed in the product of fruit crops. The significance of Remote Sensing, along with Geographical Information System and Global Polar Satellite (GPS), is the original step towards the successful implementation of Site-Specific Crop Management (SSCM) in fruit crops. The operation of Site-Specific Crop Management (SSCM) in horticultural crops, particularly fruit crops, can maximize resource application and increase net returns. Geo-spatial technology used for orchard demarcation and geographical analysis can give supplementary information for decision- making operation, including fruit production estimation, area estimation, quantification and timing of exact and appropriate use of fungicides, toxin, and irrigation to control disease and pests.

Remote sensing

The wisdom and art of learning about an object, region, or phenomenon by analysing data collected by a device that isn't close proximity to the subject of the inquiry is known as remote sensing. Or it may be defined as the process of carrying information about land, water or an object without any physical contact between the detector and the subject under observation (Remote – Not in contact with an object and Sensing - Getting information). The multidisciplinary field of remote sensing encompasses a variety of scientific disciplines, including electronics, spectroscopy, computer wisdom, satellite launching, optics, and photography. Introductory knowledge of all these sciences is very essential and it's being exploited in operation of remote sensing.

Fundamentals of remote sensing

Remote sensing Stages

In the stages of remote sensing, incoming radiation interacts with the targets of interest. This is demonstrated by the operation of imaging systems, which incorporate the seven factors listed below.

1. Energy Source or Illumination (A) The first demand for remote sensing is the presence of an energy source that can illuminate the target of interest or supply electromagnetic radiation.

2. Radiation and the Atmosphere (B) The energy encounters and reacts with the atmosphere it passes through on its way from its source to its destination. As the energy moves from the target to the sensor, this interaction occurs a second time.

3. Interaction with the Target (C) Depending on the characteristics of the target and the radiation, the energy interacts with the target after travelling through the atmosphere.

4. Recording of Energy by the Sensor(D) A device called a sensor (remote; not in contact with the target) gathers and records the electromagnetic radiation once the energy has been scattered by or released from the target.

5. Transmission, reception and Processing (E) The sensors recorded energy is transferred, constantly electronically, to a receiving and processing unit, where it's converted into a digital or hard-copy image.

6. Interpretation and Analysis (F) The image is reused and also visually, digitally, or electronically estimated to gain information about the illuminated object.

7. Operation (G) The last step in the remote sensing process is applying the knowledge we've learnt about the target from the picture to gain a deeper understanding of it, uncover new information, or help break a specific issue.

Electromagnetic radiation

The first demand for remote sensing is to have an energy source to illuminate the target (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation.

Electromagnetic radiation consists of an electrical field (E) and a magnetic field (M). Both these fields travel at the speed of light (C). Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing. These are the wavelength and frequency.

Electromagnetic spectrum

The electromagnetic radiation ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves) (fig.2). The several regions of the electromagnetic spectrum useful for remote sensing are as follows.

1. **Ultraviolet or UV radiation -** The shortest wavelengths seen in this region of the radiation are useful for remote seeing. The violet region of the visible wavelengths is n't reached by this light. When exposed to ultraviolet light, certain materials on the Earth's surface substantially rocks and minerals release visible light.

2. **Visible radiation-** The light which our eyes can see is part of the visible spectrum. The visible wavelengths cover a range from 0.4 to 0.7 µm. The longest visible wavelength is red and the shortest is violet.

3. **Infrared spectrum-** The wavelength range it covers is from 0.7 µm to 100 µm. Grounded on its radiation characteristics, the infrared region can be separated into two groups reflected infrared and emitted, or thermal, infrared. The wavelengths of the reflected infrared range from 0.7 µm to 3.0 µm. In substance, the radiation that's released from the Earth's surface as heat is known as the thermal infrared zone. The wavelength range covered by thermal infrared is 3.0 µm to 100 µm.

4. Microwave spectrum- It encompasses the longest wavelengths- roughly 1 mm to 1 m that are employed in remote sensing. While the longer wavelengths come closer to the wavelengths used for radio broadcasts, the shorter wavelengths have characteristics more like to those of the thermal infrared area.

Remote sensing Platforms :

Substantially there are three types of platforms used in remote sensing.

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Ground Based- When it comes to recording comprehensive information about the surface, ground- based sensors are more useful than upstanding or space- grounded sensors. This can occasionally be used to more characterize the target that the other sensors are imaging, which helps to more interpret the information contained in the imagery. The sensors could be mounted on a tripod stage, buildings, a crane, a altitudinous structure, a ladder, a car, etc.

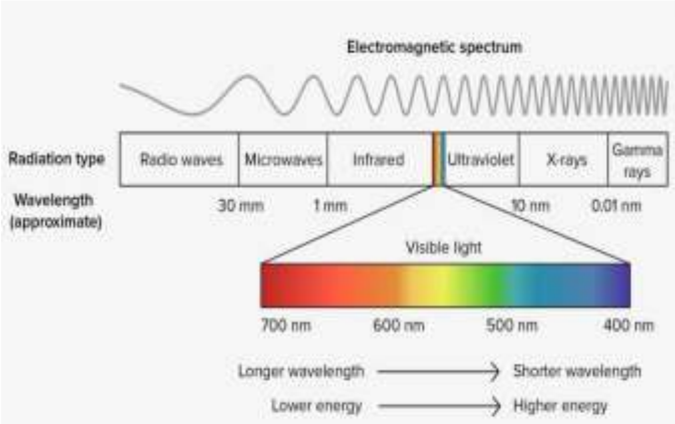

Fig 2: Electromagnetic Spectrum

Air Borne- Aerial platforms are primarily stable wing aircraft, although helicopters are sometimes used. Aircraft are used to collect veritably detailed images and facilitate the collection of data over nearly any portion of the Earth's surface at any time.

Space Borne- In space, remote sensing is occasionally conducted from the space shuttle or, more generally, from satellites.

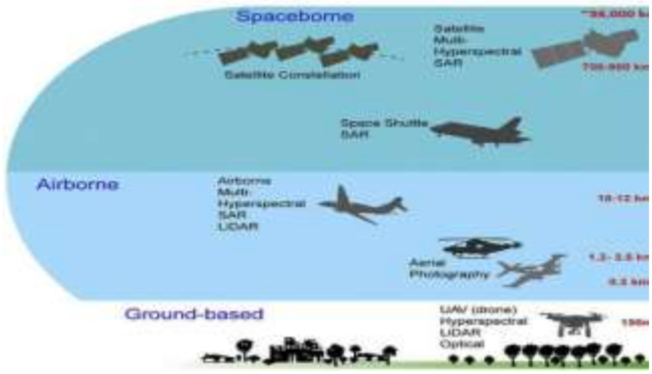

Fig 3: Remote Sensing Platforms

Applications in Fruit Crops

1. Mapping of fruit orchards and estimation of cultivable area.
2. Land assessment and suitability in fruit crops.
3. Crop inventory of fruit crops.
4. Precise application of fertilizer in fruit orchards.
5. Detection of abiotic stress in fruit crops.
6. Quality assessment of fruit crops.
7. Detection of pest occurrence in fruit crops.
8. Detection of disease incidence in fruit crops.

Way forward

Remote sensing in fruit crop management is moving toward high-resolution monitoring, AI-driven analysis, and integration with IoT sensors to enhance precision farming. It enables early detection of stress, pests, and diseases, optimizes irrigation and harvest timing, and supports climate risk assessment. Future progress depends on improving accessibility, farmer training, and user-friendly decision support tools for sustainable and efficient fruit production.

Conclusion

Remote sensing is rapidly proving their potential for applications in fruit crop area estimation, crop biomass detection, soil properties, soil moisture, nutrient content, green fruit counts, crop yield estimation, damage by biotic and abiotic stresses etc. These technologies are authentic resources of information for identifying, classifying, mapping, monitoring and planning of natural resources and disaster mitigation and management. They have a promising future for site specific management, precision horticulture, market planning and export. Remote Sensing has proved to be an influential tool for the environmental monitoring in several instances.

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Enhancing production of fruit orchard and income of the growers through canopy management

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Plant consists of two parts aerial and underground. Aerial part is constituted by bole and branches. Bole means undivided stem of the plants. The branches refer to shoot part of the plant. Shoot remains covered by leaves.

Canopy

Canopy defined as overall spread of the plant. In another word canopy is umbrella of the plant. It is the aerial portion of the tree, which is the organization of the shoots, leaves and fruit of the plant. E.g. Litchi, Mango.

2. Canopy manipulation

Canopy manipulation is the process of manipulating tree canopies to optimize the production of quality fruits. Canopy manipulation affects the quantity of sunlight intercepted by trees. Small trees are better at capturing and converting sunlight into fruits than large trees.

3. Canopy management

A series of operations on the above ground portion of the tree, aiming towards maximized production of quality fruits per unit canopy area. Canopy management is the manipulation of tree canopy to optimize its production potential with excellent quality fruits. For example- training and pruning operations.

4. Steps of canopy management

a) Selecting appropriate planting system.
b) Initial frame development.
c) Training the plants with open centre.
d) Centre opening of grown-up trees.
e) Allow the canopy to grow horizontally.
f) Pruning of the shoots and excessive growth.

5. Features of ideal canopy

a. Strong frame of primary branches.
b. Wider crotches in scaffold branches.
c. Well distributed secondary and tertiary branches.
d. Sufficient fruiting terminals in most productive areas.

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e. Healthy foliage with high photosynthetic efficiency.
f. Enough space for air circulation inside canopy.
g. Adequate shade to protect the fruits from sunburn.

6. Basic principles in canopy management

a) Maximum utilization of light.
b) Convenience in carrying out the cultural practices.
c) Facilitating aeration inside the canopy.
d) Controlled plant structure including stature.
e) Maximizing the quality, yield and productivity.
f) Economy in obtaining the required canopy architecture.

7. Object of canopy management

a) Remove apical dominance for encouraging branching.
b) Remove unproductive over crowded branches.
c) Remove diseased and dead wood branches.
d) Control overall size of fruit tree.
e) Regulate fruiting for regular cropping.
f) Give particular training.

8. Importance of canopy management

a) For proper density of trees per unit area.
b) For proper use of natural resources.
c) For better management of agronomical activities.
d) For good quality fruits.
e) Increase in production per unit area.
f) Annually regular fruit production.

9. Techniques of canopy management

i. Dwarf rootstock

S. No.	Name of fruit plant	Dwarfing rootstock	Characteristics
1.	Apple	M-9 M-27	Dwarf, most widely used Ultra dwarf
2.	Ber	*Zizypus nummularia*	Dwarf, salt tolerant
3.	Cherry	Colt Mazzard	
4.	Citrus	Troyer citrange Flying Dragon Trifoliate orange	Dwarfing for kinnow Most dwarfing
5.	Guava	Pusa Srijan	Dwarfing for Allahabad Safeda
6.	Mango	Vellaicollumban Rumani	Dwarfing for Alphonso, Dashehari
7.	Pear	Quince C	Most ultra dwarf
8.	Peach	Rubira, Tetra	Semi-dwarfing
9.	Plum	Pixy	Ultra dwarf

ii. Dwarf scion

S. No.	Name of fruit plant	Dwarfing Scion
1.	Apple	Red Spur Oregon Spur
2.	Banana	Dwarf Cavendish
3.	Grape	Gulabi Bhokri
4.	Mango	Amrapali
5.	Spota	PKM-1,21 CO.3
6.	Papaya	Pusa Nanha
7.	Peach	Redhaven

iii. Training

Judicious removal of plant part to develop a proper shape of plant capable of bearing heavy crop load.

Objectives of Training

a) To develop strong framework of tree.
b) To control and regulate shape of trees
c) To have a better crotch angle between scaffold branches of the trees.
d) To facilitate interception of sunrays to each and every part of trees.
e) To remove water sprout.
f) To develop a balance between vegetative and reproductive growth of tree.

Systems of Training

(a) Central leader system

In this system the central leader branches are allowed to grow indefinitely so that it will grow more rapidly

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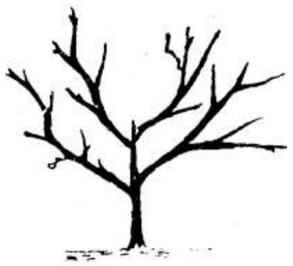
and vigorously than the side branches and tree became tall. Such a tree bears fruit more near the top. The lower branches are less vigorous and less fruitful. The tree attains robust shape. The first branch is allowed to grow at 45 to 50cm height from ground level and other branches are allowed to grow on main stem at a distance of 15 to 20cm.

Central leader system

(b) Open centre system

In this system, when the plant attains a height of 40 to 50 cm, it is beheaded. From the subsequent vegetative growth, 4-5 branches well scattered, arranged and distributed all around the main stem are selected. This system facilitates easy carrying out of operations. It allows full sunshine to reach each branch. The plant takes a bowl shape.



Open centre system

(c) Modified leader system

It is intermediate between the above systems. In this system, the main stem is allowed to grow for 4 to 5years. After that, it is cut at a height of 120 to 150cm from ground level. It is developed by first training the tree to the leader type by allowing the central axil to grow unpruned for the first four or five years. Then central stem is headed back and lateral branches are allowed to grow as in the open centre system

Modified leader system

iv. Pruning

Pruning may be defined as the art and science of removing portion of plant to improve its shape, growth, flowering and to improve the quality of the product**.**

Objectives of Pruning

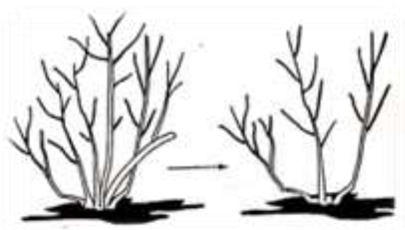
a) To control flowering and fruiting.
b) To augment production in plants which bear on new shoots.
c) To obtain regular bearing.
d) To remove disease, damaged, insect infested and weak shoots.
e) To thin out flowers and fruits.
f) To ensure access to sunlight to bearing shoots.
g) To invigorate the plants.
h) To have a balance between vegetative and reproductive growth.

Types of pruning

(a) Thinning

Complete removal of plant part like stem, branches, leaves, fruits etc

For example- Grapes, Peach, Plum.



Thinning

(b) Heading back

It consists of removal of terminal part of the branch leaving basal part intact.

For example- Guava, Mango.

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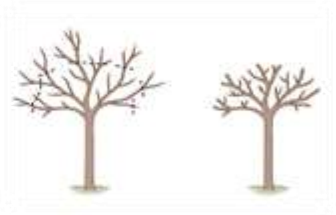

Heading back

(c) Ringing/Girdling

In ringing circular ring of bark measuring 2-3 mm is removed. For example- Mango, Grapes.

Ringing

(d) Skirting

removal of ground touching branches is known as skirting. For example- Citrus, Guava, litchi, Jamun, Mango.

Skirting

(e) Notching

It is the process of making “V” shape incision above the bud. For example- Poona Fig.

Notching

(f) Nicking

In this process “V” shape incision is prepared below the bud. For example- Poona Fig, Apple.

Nicking

(g) Stumping

Stumping means cutting down tree to 4 to 5 feet in height from ground level leaving 2 feet long stubs of the large scaffold branches.

For example- Mango, Jamun, Litchi, Spota.

Stumping

(h) Stag horning

In stage horning, trees are cut back to about 15 to 20 feet in height. For example- Mango, Jamun, Litchi, Spota.

Stag horning

(i) Root pruning

To check excess vegetative growth, root pruning is done. It helps in diverting food reserve towards

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reproductive growth and thus brings the fruit plants into bearing. For example- Citrus, Apple, Pear.

Root pruning

(j) Leaf pruning

The type of pruning has been found useful in balancing canopy growth in guava. Terminal two pairs of leaves of shoot is removed.

Leaf pruning

v. PGRs

Chemical substances which regulate growth of the plants are known as growth regulators. It may be natural or synthetic in nature. Naturally accruing substances in plant which has growth regulatory role is known as phytohormones. The substances which work similar to phytohormones but synthesis artificially are known as plant growth regulators. Based on their actions, plant growth regulators are classified in two groups:

a-Growth promoters

Auxin

Auxin has inhibitory role on lateral bud growth of the plant. Auxin favors flowering and fruit setting. When terminal portion where auxin is synthesis is removed the lateral bud sprout. Auxin decreases negative geotropism of shoot and it favors widening of crotch angle.

Cytokinin

Cytokinin restricts terminal growth of the plant. It promotes lateral growth and height of lateral shoot by being involved in cell division.

Gibberellin

Gibberellin increases internodal length. It is particularly effective in dwarf rosette plant. When gibberellin is sprayed in plant the dwarf variety of the same plant becomes taller and it looks like taller variety of the same species.

b-Growth inhibitors/retardants

Ethylene

It is known as ripening hormone. Ethylene promotes flowering. Spray of minute concentration of ethephon bring fruit thinning, but it may be in lower amount, however it may have very high foliage shedding and reduction of plant growth. Spray of 25 ppm ethephon is followed to bring flowering in pineapple, generally ethephon find commercially application for ripening of fruit and degreening of lemon.

Paclobutrazol

It is anti-gibberellin compound. It checks vegetative growth. After application of paclobutrazol the internodal length of plant is minimizes. Paclobutrazol favours flower bud emergence, flower bud density, increase fruit set, and improves the quality of fruit. In mango 1ml/mitre canopy spread in mango used to bring regulatory in bearing. Usually, 2000 ppm paclobutrazol is effective in checking vegetative growth and inducing reproductive growth

Chlormequat

Chlormequat is a growth retardant which check the plant growth and minimizes canopy growth. It shortens internodal length, check growth and promotes flowering. It is accumulated in meristematic region, leaves and young tissues. When it is applied, after 6 hours its uptake by roots its resulted in 20 % growth inhibition after 2 weeks of spray.

Morphactins

Morphactins are applied in the plant by twining chemical socked around the ring made over the stem of the plant. It checks growth of the plants. This is applied to the plant through cincturing the bark. When morphactin was applied there was 20-30 % reduction in canopy area, there was minimize 33-50 % root growth, of course the growth was recovered after one season of application.

10. Conclusion

It can be concluded that fruit production can be regulated through canopy management. It includes use of dwarf rootstock and scion, training and pruning system and use of plant growth regulators to achieve higher fruit production with improved quality that helps ultimately to earn better income to growers.

11. References

Arora, R. and Singh, N. (2017) Growth Regulators for Yield and Quality Enhancement in Litchi (*Litchi chinensis* L)- A review. *International Journal of Current Microbiology and Applied Sciences*, 6**(8)**: 2152-2159.

Muthukumar P. and Selvakumar R. (2017) Glaustas Horticulture. New Vishal Publications, New Delhi.

Pal, V., Chandra, N., Kumar, A. and Kumar, M. (2016) Response of pruning in canopy management and high-density planting in guava orchard under western Uttar Pradesh condition. *South Asian Journal of Food Technology and Environment*, 2**(3&4)**: 458- 464.

Roy, A., Viswanath, M., Gowthami, L. and Nanda, S. P. (2021) Training: A tool for canopy management in fruit crops. *The Pharma Innovation Journal*, 10**(6)**: 361-364.

Srivastava K. K. (2007) Canopy Management of Fruit Crops. International Book Distributing Company, Lucknow.

Singh, J. (2018) Basic Horticulture. Kalyani Publishers, Ludhiana.

Singh, J. (2022) Drylands Horticulture. Kalyani Publishers, Ludhiana.

Singh, R. P., Singh A. K., Singh, A. and Singh, M. (2022) Growth, yield and quality attributes of guava as influenced by canopy management practices: A review. *The Pharma Innovation Journal*, 11**(11)**: 1723-1730.

Wani, R. A., Din, S., Khan, M., Hakeem, S. A., Jahan, N., Lone, R. A., Baba, J. A., Parray, G. N. and Khan, J. A. (2021) Canopy management in fruit crops for maximizing productivity. *International Journal of Chemical Studies*, 9**(3)**: 160-165.

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Smart Farming with Real-Time Nitrogen Management (RTNM) in Cereal Crops

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Nitrogen is a critical nutrient for cereal crop productivity, yet inefficient nitrogen management in Indian agriculture leads to significant economic losses and environmental degradation. Real-Time Nitrogen Management (RTNM) has emerged as an innovative approach to optimize nitrogen use by synchronizing fertilizer application with the crop's actual nitrogen demand at various growth stages. This adaptive strategy improves nitrogen use efficiency (NUE), reduces losses through volatilization, leaching, and denitrification, and mitigates associated greenhouse gas emissions. RTNM employs various tools and technologies such as the Leaf Color Chart (LCC), SPAD meter, GreenSeeker optical sensors, and digital decision support systems, which enable precise, site-specific nitrogen management in major cereals like rice, wheat, and maize. Field studies demonstrate that RTNM enhances NUE by 10–30%, increases yields by 5–15%, reduces fertilizer input costs, and lowers nitrous oxide emissions by up to 18%. Despite these benefits, adoption challenges persist due to limited farmer awareness, access to advanced tools, training gaps, and regional variability in agroecological conditions. Opportunities to expand RTNM use include government schemes, public-private partnerships, mobile technology platforms, participatory farmer training, and ongoing research and development. Integrating RTNM within climate-smart agriculture frameworks supports sustainable intensification by balancing productivity, profitability, and environmental stewardship. Thus, RTNM offers a practical, cost-effective, and eco-friendly solution for enhancing cereal crop production in India while contributing to environmental sustainability and climate change mitigation.

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Nitrogen is one of the most vital nutrients for cereal crop production, significantly influencing plant growth, yield, and quality. However, inefficient nitrogen management is a prevailing issue in Indian agriculture. Excessive application not only leads to economic losses but also causes environmental problems such as nitrate leaching, greenhouse gas emissions, and eutrophication of water bodies (Ladha et al., 2005). On the other hand, under-application can result in nutrient deficiencies and yield losses.

In India, the recommended nitrogen application varies across cereal crops and agroecological zones. For example, rice typically requires 100–150 kg N/ha, wheat 120–150 kg N/ha, and maize around 100–180 kg N/ha depending on soil fertility and climatic conditions (TNAU, 2023). Despite these recommendations, nitrogen use efficiency (NUE) remains low in Indian cereal systems, often in the range of 30–50% (Ladha et al., 2005; Sharma et al., 2015). This implies that nearly half or more of the applied nitrogen is lost to the environment.

Nitrogen losses occur through several pathways. In flooded rice systems, ammonia volatilization can account for 20–60% of applied nitrogen, while nitrate leaching and denitrification are major loss mechanisms in upland crops like wheat and maize (Pathak et al., 2010). These losses not only reduce fertilizer effectiveness but also contribute to pollution and climate change through emissions of nitrous oxide, a potent greenhouse gas.

Nitrogen Use Efficiency (NUE) in cereal crops in India typically ranges from 30–50%, meaning that only about one-third to half of the applied nitrogen is utilized by the crop, while the rest is lost to the environment. Low NUE not only affects crop productivity but also contributes to environmental degradation. RTNM has been shown to improve NUE by 10–30%, depending on the crop and management conditions. By aligning nitrogen supply with actual crop needs, RTNM reduces losses and improves nitrogen uptake efficiency, making it a promising tool for sustainable intensification of cereal production in India.

Real-Time Nitrogen Management (RTNM) emerges as a practical, cost-effective, and eco-friendly approach to address these challenges. RTNM focuses on matching nitrogen supply with the actual crop demand at different growth stages, optimizing nitrogen use efficiency (NUE), and minimizing environmental footprints.

Real-Time Nitrogen Management (RTNM)

RTNM is an adaptive nitrogen application strategy that provides nitrogen to crops based on real-time assessments of their needs. Unlike traditional blanket recommendations or fixed split applications, RTNM involves monitoring crop health indicators such as leaf color and canopy reflectance to guide nitrogen application. The underlying principle of RTNM is that crop nitrogen status changes over time and is influenced by factors like soil fertility, weather, and management practices. Therefore, real-time decisions help synchronize nitrogen supply with crop uptake, improving productivity and environmental sustainability (Singh et al., 2002).

Tools and Technologies for RTNM

Several tools have been developed to facilitate RTNM in cereal crops:

a. Leaf Color Chart (LCC): A simple, affordable, and widely used tool, the LCC consists of green color shades that help farmers visually assess the nitrogen status of the crop. If the leaf color is lighter than the threshold value on the LCC, nitrogen should be applied. This tool is especially effective in rice cultivation (Buresh et al., 2010).

b. SPAD Meter: A chlorophyll meter that measures leaf greenness non-destructively, indicating the relative nitrogen content. Though more expensive than LCC, SPAD meters offer precise readings useful for high-value crops and research applications.

c. GreenSeeker: An optical sensor that measures Normalized Difference Vegetation Index (NDVI) to assess crop vigor and guide nitrogen application. It is

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useful in wheat and maize crops and is being increasingly adopted in precision agriculture.

d. Mobile Apps and Decision Support Systems (DSS): Digital platforms like Nutrient Expert, FarmPrecise, and Crop Manager provide customized nitrogen recommendations based on field data, weather, and crop models. These are increasingly accessible via smartphones and are transforming on-farm nutrient management.

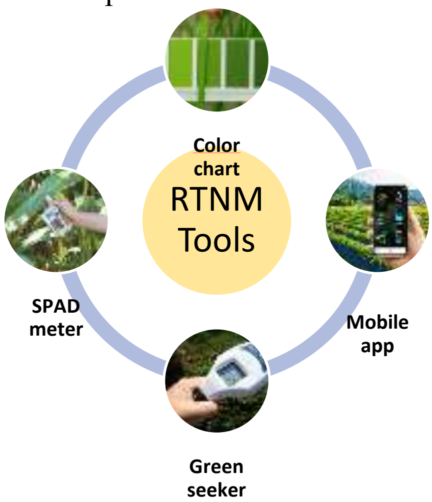

Figure 1. RTNM tools used for Nitrogen management in agriculture

How RTNM Works in Major Cereal Crops

a. Rice: RTNM in rice often utilizes the LCC to determine the timing and need for nitrogen applications. Farmers are advised to compare the topmost fully expanded leaf color with the LCC at regular intervals (usually every 7-10 days) starting from 14 days after transplanting. Nitrogen is applied only if the leaf color is lighter than the critical threshold (usually LCC shade 4) (Buresh et al., 2010).

b. Wheat: In wheat, GreenSeeker is commonly used to apply nitrogen at the crown root initiation (CRI) and later growth stages. The device helps determine the NDVI, which correlates with crop nitrogen status. Based on NDVI readings, farmers can apply variable rates of nitrogen tailored to crop needs, improving NUE and yields (Sharma et al., 2015).

c. Maize and Other Cereals: RTNM in maize involves split applications of nitrogen guided by canopy reflectance sensors or SPAD readings. The technique helps reduce nitrogen losses, particularly in rainfed conditions. Studies show that RTNM can significantly enhance yield and economic returns in maize (Satyanarayana et al., 2007).

Advantages of RTNM for Farmers

Real-Time Nitrogen Management (RTNM) offers a host of agronomic, economic, and environmental advantages for cereal farmers, with numerous success stories reinforcing its practical value on the ground.

a. ***Improved Nitrogen Use Efficiency (NUE)***
By synchronizing nitrogen application with actual crop demand, RTNM enhances nitrogen uptake and utilization. Studies have shown that RTNM can improve NUE by 10–30%, thereby reducing losses and enhancing fertilizer efficiency (Pathak et al., 2018).

b. ***Increased Yields and Farm Profitability***
Farmers practicing RTNM consistently report higher yields. In Punjab and Haryana, widespread adoption of LCC-based RTNM in rice resulted in yield increases of 5–10%, alongside fertilizer savings of up to 20–30 kg N/ha. In wheat and maize systems using GreenSeeker or SPAD, yield improvements of 10–15% have been observed (Singh et al., 2020; Tiwari et al., 2022).

c. ***Reduction in Input Costs***
By avoiding blanket or unnecessary nitrogen applications, farmers reduce fertilizer expenses. For example, a farmer in Karnal district, Haryana, saved ₹1,200 per hectare in fertilizer costs while gaining an additional 800 kg/ha in rice yield using LCC-based RTNM (Dwivedi et al., 2019).

d. ***Environmental Protection***
RTNM adoption reduces excess nitrogen application, thereby lowering greenhouse gas emissions. Studies report a reduction of nitrous oxide emissions by 12-18% and nitrate leaching by 10-15% under RTNM regimes (Kumar et al., 2021).

e. ***Empowerment through Technology and Knowledge***

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The adoption of simple tools like the Leaf Color Chart (LCC) and more advanced technologies like GreenSeeker has empowered farmers with data-driven decision-making capabilities. Farmer Field Schools (FFS), Krishi Vigyan Kendras (KVKs), and digital platforms like Nutrient Expert have played vital roles in disseminating RTNM techniques.

8. Challenges and Opportunities in Utilization of RTNM in Indian Agriculture

Despite the proven benefits and growing interest in Real-Time Nitrogen Management (RTNM), several challenges limit its widespread adoption across Indian agriculture. At the same time, there are significant opportunities to overcome these barriers and expand its impact.

1. Challenges

a) *Limited Awareness and Knowledge*
Many smallholder farmers lack awareness of RTNM tools and techniques. Traditional practices and reluctance to change pose hurdles to adoption.

b) *Access to Appropriate Tools*
While simple tools like the Leaf Color Chart (LCC) are affordable, advanced sensors such as GreenSeeker and SPAD meters are expensive and often unavailable to small and marginal farmers.

c) *Training and Capacity Building Needs*
Effective use of RTNM requires proper training in interpreting tool readings and making timely nitrogen application decisions. Limited extension services restrict farmer capacity building.

d) *d) Variability in Agroecological Conditions*
India's diverse agro-climatic zones and soil types require site-specific calibration of RTNM tools, complicating uniform recommendations.

e) *e) Infrastructure and Support Systems*
Inadequate supply chains for fertilizer and sensors, along with poor internet and mobile connectivity in some rural areas, hamper the implementation of digital decision support tools.

2. Opportunities

a) *Government Schemes and Policy Support*
Programs like the Soil Health Card Scheme, National Mission on Sustainable Agriculture (NMSA), and PM-KISAN can integrate RTNM promotion through subsidies, training, and awareness campaigns.

b) *Public-Private Partnerships (PPP)*
Collaborations between government agencies, research institutions, private companies, and NGOs can facilitate development, distribution, and training on RTNM tools.

c) *Digital Agriculture and Mobile Technology*
Increasing smartphone penetration offers a platform for app-based nitrogen management tools such as Nutrient Expert and FarmPrecise, enabling real-time, location-specific recommendations.

d) *Farmer Field Schools and Demonstrations*
Scaling up participatory training programs and on-farm demonstrations can build farmer trust and skills in RTNM.

e) *Research and Development*
Continuous R&D can refine sensor technologies, develop low-cost devices, and customize RTNM protocols for different crops and regions.

f) *Climate-Smart Agriculture Integration*
RTNM's role in reducing nitrogen losses and greenhouse gas emissions aligns it with India's climate-smart agriculture goals, opening avenues for carbon credit schemes and green financing.

Conclusion

Real-Time Nitrogen Management (RTNM) offers significant advantages for cereal crop production in Indian agriculture. By optimizing nitrogen fertilizer application based on crop needs, RTNM enhances nitrogen use efficiency, leading to higher yields and improved profitability for farmers. It reduces excessive fertilizer use, thereby minimizing environmental impacts such as greenhouse gas emissions and nitrate leaching. Tools like the Leaf Color Chart and GreenSeeker have proven effective and practical, facilitating wide adoption among farmers across diverse agro-climatic zones. RTNM thus supports sustainable and climate-smart agriculture by balancing productivity with environmental stewardship.

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Plant Whispers: Using Plant Electrophysiology for Real-Time Farm Communication

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Imagine walking into your field one morning—and your plants *ping* you.

"Hey, we're thirsty."
"Something's chewing on us."
"The soil's off today."

It sounds like magic, but its real science. Welcome to the future of farming: **plant whisper networks**. This isn't poetry—it's **plant electrophysiology** meeting AI and IoT to let crops communicate in real-time. Yes, your plants can actually *talk*

What Is Plant Electrophysiology?

Plant electrophysiology is the study of electrical signals generated and propagated within plants. Like the human nervous system, plants use electrical impulses—called **action potentials** and **variation potentials**—to respond to stimuli such as light, drought, touch, or pest attacks. These electrical changes are subtle but measurable using sensitive sensors attached to plant leaves or stems.

The Whisper Network Concept:

A **plant whisper network** refers to a connected system where these bioelectrical signals are continuously monitored, interpreted, and transmitted across a digital farm network. By embedding sensors and IoT devices in key plants throughout a field or greenhouse, farmers can tap into the plants' "silent language"—detecting stress signals, growth changes, and even early signs of disease or pest infestations in real time. This network acts as a **biological early warning system**, amplifying plants' natural ability to sense and react to their environment and translating that data into actionable insights.

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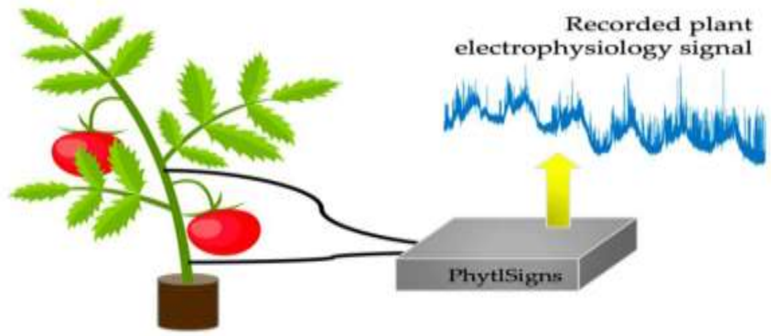
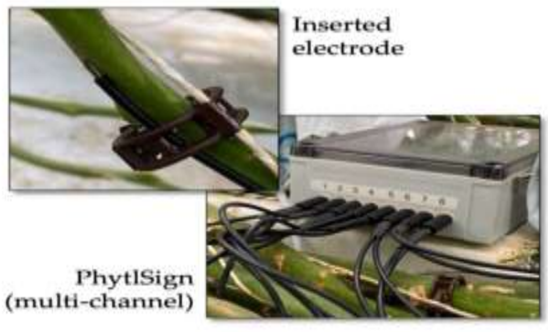
How It Works

1. **Sensor Placement**
   Electrodes are non-invasively attached to plant tissues to monitor voltage fluctuations. These are typically thin, flexible materials that won't harm the plant.
2. **Signal Detection**
   As the plant reacts to environmental changes, it generates electrical signals that are captured by the sensors.
3. **Data Transmission**
   The signals are transmitted wirelessly to a central system using IoT gateways or edge devices.
4. **AI-Driven Interpretation**
   Machine learning algorithms analyze the patterns and correlate them with known stressors (e.g., water deficiency, pathogen attack, high salinity).
5. **Real-Time Alerts and Automation**
   When anomalies are detected, farmers receive alerts via mobile apps or dashboards, allowing them to make timely interventions. In advanced setups, this can even trigger automated irrigation, nutrient dosing, or pest control.





Listening to Lettuce in the Netherlands

In the Wageningen University & Research Greenhouses in the Netherlands—one of the world's most advanced agricultural research centers—scientists have been experimenting with plant electrophysiology sensors attached to crops like lettuce, tomatoes, and cucumbers.

What They Did:

- Researchers attached **electrodes** to lettuce leaves to record tiny bioelectrical signals.
- These signals changed when the **temperature rose too high**, or when **irrigation was delayed** by even a few hours.
- Using this data, AI models were trained to interpret plant signals and correlate them with specific environmental changes (e.g., water stress, nutrient deficiency).

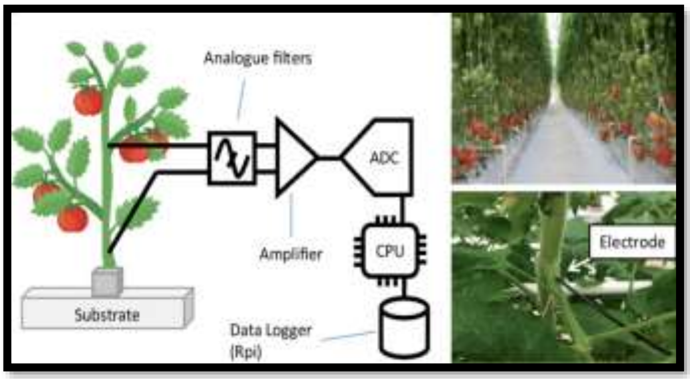
PhytlSigns – Giving Plants a Voice

PhytlSigns, developed by Vivent, is one of the world's first commercial platforms that enables plants to "speak" through bioelectrical signals. It's essentially a "Fitbit for plants", designed to bring plant electrophysiology out of the lab and into real-world farms and greenhouses. In tomato greenhouses, PhytlSigns was able to detect disease stress up to 10 days before any visible symptoms appeared. PhytlSigns showed that plants begin to send stress signals even when soil moisture levels are *technically* within normal range. By responding to the plant's own feedback, growers were able to fine-tune irrigation schedules and reduce water waste. When plants are physically disturbed (e.g., by aphids or caterpillars), PhytlSigns can detect sudden electrical changes—giving a heads-up before the damage becomes visible.

Research Institutions in India

Several Indian institutions are at the forefront of agricultural research and can play a pivotal role in advancing plant electrophysiology:

- **Indian Institute of Spices Research**: Engaged in plant physiology and biochemical studies, which are foundational for



- understanding plant responses to environmental stresses.
- **National Research Centre on Plant Biotechnology, Hisar**: Focuses on plant biotechnology research, which can complement electrophysiological studies for crop improvement.

Conclusion:

Plant whisper networks, powered by plant electrophysiology, are revolutionizing agriculture by allowing plants to communicate real-time stress signals—long before visible symptoms appear. From smart irrigation in European greenhouses to early pest detection using platforms like PhytlSigns, this technology is already transforming how we grow food. In India, where water scarcity, pest outbreaks, and crop losses are major challenges, integrating plant electrophysiology with smart farming tools offers massive potential. With growing interest from research institutions and the rise of precision agriculture, India is well-positioned to lead a new era of plant-first, tech-driven farming.

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Citizen Science in Sustainable Agriculture

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Citizen science in sustainable agriculture empowers farmers and communities to actively contribute to scientific research, bridging the gap between formal studies and real field conditions. By sharing local knowledge, data, and observations, citizens enhance data quality and promote faster adoption of sustainable practices. Key areas include pest and disease surveillance, soil health monitoring, crop variety assessment, climate change adaptation, and water management. Advancements in digital tools and ICT platforms enable real-time data collection and informed decision-making. Despite challenges like limited awareness and technology access, citizen science offers great promise for building inclusive, resilient, and environmentally sound agricultural systems.

Introduction

Citizen science is a participatory method of scientific study by non-professional scientists, including farmers, students, and communities. They provide valuable observations, gather data, and transfer local information that enables scientific investigation and innovation. Citizen science has become an effective tool in agriculture that promotes the participation of farmers in monitoring and responding to crop, pest, soil, and climate-related challenges. This participatory framework not only makes science more democratic but also creates a perception of ownership and responsibility among the stakeholders towards sustainable farming practices. Ebitu *et.al.*2021

Relevance to Agriculture

For agriculture, citizen science has tremendous value. Farmers are the most immediate witnesses of their land and thus automatically serve as real-time data gatherers and innovators. Their participation

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bridges the distance between institutional research and farm-level farming realities. Conventional farm research typically takes a top-down strategy, where interventions are developed in laboratories or research stations and subsequently scaled up to farmers. Such a model may not in all cases be able to capture the diversity and heterogeneity of actual farm systems. Citizen science allows farmers to co-design knowledge, in order to make research more participatory, localized, and sensitive to local needs. Mourad *et.al.* 2020.

By engaging farmers in scientific inquiry-like pest monitoring, soil health, or variety testing-scientists can produce stronger, adaptive, and locally specific solutions. This improves decision making, not only at the farm level but also in the development of policies and practices that are aligned with the grassroots experience.

Source: https://www.theindianwire.com/agriculture

Why Citizen Science for Sustainable Agriculture?

Sustainable agriculture seeks to grow food in ways that are ecologically sustainable, economically viable, and socially equitable. Citizen science is a perfect fit for this vision through enlisting local people to address their own issues. Farmers are able to monitor changes in weather patterns, report emerging diseases or pests, and monitor soil conditions-all of which are going toward adaptive, climate-smart agricultural strategies. Additionally, citizen science fosters environmental stewardship since farmers learn more about ecosystem behavior and develop more sustainable practices. It also promotes digital tool utilization and data-driven agriculture, making precision agriculture and intelligent resource planning for a sustainable agriculture future possible. Van De Gevel *et.al.* 2020.

Objectives and Benefits of Citizen Science in Sustainable Agriculture

Objectives

The incorporation of citizen science into agricultural systems is shaped by various fundamental objectives oriented toward building sustainability and inclusivity. Among the main goals is to promote farmer engagement in agricultural research. Through the direct involvement of farmers in experimentation and data collection, agricultural research is made more responsive, pragmatic, and relevant to field conditions.

Another primary aim is enhancing data collection and validation at the grassroots. Conventional studies usually experience difficulties in covering various agro-climatic zones and reporting field-level variations. Citizen science bridges such gaps by facilitating extensive and real-time data collection, such that information collected is reflective of the complexity of local settings.

Another aim is to support environmentally and sustainably friendly practices by engaging the agricultural community actively. When farmers are engaged in monitoring ecological trends, they are more aware of the effect of their agricultural practices and tend to use sustainable alternatives.

Finally, citizen science works towards region-based solutions. Due to the variety of soil types, crops, climate, and socio-economic conditions in India and other agrarian economies, standardized solutions rarely work. Data and experiences driven by citizens can result in the production of tailored practices and technology that are more appropriate to local requirements.

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Benefits

Citizen science has numerous benefits to be brought to the agriculture industry, especially in enhancing sustainability. Perhaps the greatest benefit is the empowerment of farmers. When farmers are engaged in the observation, collection, and analysis of agricultural data, they acquire scientific literacy but also enhance their decision-making ability. This experiential engagement results in better-informed and self-assured farming activities.

The other important benefit is improved data quality. Local farmers have a very close knowledge of their surroundings and can pick up minute changes or trends which might go unnoticed by remote researchers. This local knowledge improves the accuracy and relevance of context of agricultural research.

Secondly, citizen science promotes the quick sharing of innovations. Members of these projects tend to spread their experience among colleagues, accelerating the diffusion of sustainable practices in communities.

Key Areas of Application

Citizen science is also playing a critical role in revolutionizing various key areas in sustainable agriculture. By involving local communities in data collection and analysis, it guarantees more locally relevant, adaptive, and participatory solutions. **1.**

1.Pest and Disease Surveillance

Farming communities serve as on-the-spot reporters of pest and disease outbreaks via mobile phones or peer networks. This decentralized method of data gathering allows for quick responses and encourages Integrated Pest Management (IPM) practices, and hence helps minimize crop losses and excessive use of chemical pesticides.

2. Monitoring Soil Health

Internet technologies enable farmers to track soil characteristics such as nutrient content, pH, and organic matter. This enables them to adopt site-specific fertilization and crop rotation practices and enhance soil quality and long-term sustainability.

3. Crop Variety Testing

With Participatory Varietal Selection (PVS), farmers field test new crop varieties and give feedback on their yield, vulnerability, and palatability. This helps ensure that the varieties promoted are suitable and acceptable locally.

4. Adaptation to Climate Change

Farmers monitor shifts in rainfall amounts, temperature, and plant reactions, providing useful information to climate adaptation efforts. This enhances community-level readiness and adaptive capacity for the onset of altering climatic conditions.

5. Water Management

Monitoring of irrigation regimes, water runoff, and water conservation efforts gives insights on the optimal use of water. Such inputs enable the formulation of efficient irrigation timetables and enhance water-saving technologies.

Digital Tools and Platforms Enabling Citizen Science

The use of digital platforms and tools has greatly enhanced the reach and impact of citizen science in agriculture.

Mobile Applications

These include mobile applications like mKRISHI, IFFCO Kisan, and Plantix that allow farmers to post images, report pest occurrences, and access expert advice. These sites allow for direct, real-time communication among farmers, researchers, and extension agents.

Online Databases and GIS Mapping

GIS-based platforms and agro-advisory portals pool data from citizen scientists to provide visual perspectives on disease distribution, rainfall, and soil health. The data informs regional decision-making and evidence-informed policy-making.

Digital Cameras and Drones

Smartphone and drone-led community-based aerial surveys boost crop health mapping and water stress mapping. The tools support precision agriculture through enhanced data accuracy.

Farmer Diaries

Farmer-kept diaries-paper or electronic-are used to log inputs, yields, and weather occurrences. When collated, these records become rich data sets for long-term trend analysis.

ICT's Role in Encouraging Citizen Science

Information and Communication Technologies (ICT) have transformed the scale of citizen science through:

- Making real-time data sharing between locations possible.
- Enhancing feedback loops among farmers, scientists, and policymakers.
- Enabling scalability and accuracy, enabling wider and more accurate coverage of agricultural patches.

Case Studies and Success Stories

Citizen science has already proven excellent success in different parts of India by enabling farmers and enhancing sustainability. The below case studies present the success of community involvement in agricultural research and innovation.

1. Pest Surveillance in Tamil Nadu

In Tamil Nadu, maize farmers facing severe Fall Armyworm infestations used a mobile-based citizen science platform to report pest sightings with photos. Scientists analyzed the reports and provided timely IPM advice. This approach reduced yield losses, improved pest response time, and lowered chemical pesticide usage, showcasing effective community-driven pest surveillance.

2. Participatory Soil Mapping in Maharashtra

In Maharashtra, participatory soil mapping empowered farmers to collect soil samples, which were analyzed with expert support. Customized fertilizer recommendations improved soil fertility, reduced input costs, and increased crop yields. This grassroots approach highlighted the effectiveness of farmer involvement in precise soil management for sustainable agricultural productivity.

3. Citizen Science in Organic Farming – Sikkim

Being India's first completely organic state, Sikkim embraced citizen science to aid its goal of organic farming. Farmers carried out on-farm trials to experiment with composting strategies and organic pest repellents, in addition to keeping very informative observation records. The collective experience among communities formed a robust support system for farmers in shifting to organic approaches. The project also reinforced local capacities and legitimized traditional ecological knowledge, creating better-resilient and sustainable organic farming systems. Steinke *et.al.* 2017.

Challenges and Limitations

Though citizen science holds tremendous potential for sustainable agriculture, its adoption is accompanied by a number of challenges that must be overcome to achieve long-term success Ryan *et.al.* 2018..

Lack of Awareness

Most farmers are ignorant of the idea of citizen science and their possible contribution to it. In the absence of adequate outreach and education, participation is limited, especially in distant or underprivileged regions.

Data Quality Concerns

The validity and precision of information gathered by non-experts can be quite different. Inadequate training or irregular methods can cause inaccurate observations or reporting, prejudicing the credibility of research findings.

Limited Access to Technology

A large digital divide remains in rural regions, with most farmers not having access to smartphones, the internet, or digital knowledge. This hinders them from engaging in tech-based citizen science activities, like mobile apps or GIS platforms.

Motivation and Incentives

To maintain farmer involvement, they need to be motivated, which can be promoted through rewards, recognition, or payment. Without appreciation or

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visible benefits, farmers can become disinterested over time.

Policy and Institutional Gaps

There are no formal policy guidelines to fund citizen science in agriculture. Concerns regarding data ownership, validation, and integration with mainstream research fall short and need institutional support to be implemented effectively.

Way Forward and Recommendations

Citizen science has significant potential to redefine the future of agriculture by engaging farmers as active participants in scientific information and sustainable solutions. Strategic policy interventions, institutional support, and inclusive partnership are needed to achieve its full potential. Policy and Institutional Support.

To bring citizen science to the mainstream in agriculture, national agricultural extension systems need to integrate it. Citizen science needs to be accepted as a true and worthful methodology for participatory research by government agencies such as ICAR, state agricultural universities, and Krishi Vigyan Kendras (KVKs). This involves:

- Developing guidelines regarding use of data, validation, and intellectual property rights.
- Instituting community innovation platforms in which farmers, scientists, and extension workers work together.
- Granting finance and acclaim to citizen science-led grassroots innovations.

Capacity Building

Farmers require proper training and resources for effective participation. There is an urgent need to:

- Hold regular training and sensitization programs on data collection methods, pest identification, monitoring weather, and mobile app usage.
- Enhance digital literacy among rural people by providing farmer-friendly digital tools and support in local languages.
- Educate extension staff to serve as facilitators who bridge field-level observations with research institutions.

Collaboration and Co-creation

Collaboration is the cornerstone of effective citizen science. Multi-stakeholder partnerships can be fortified to provide credibility, inclusiveness, and impact. These should involve:

- Research institutions to advise on scientific protocols.
- NGOs and FPOs to organize community participation.
- Private sector and agri-tech startups to offer user-friendly digital platforms and technical support.
- Participatory innovation nodes and village-level science clubs can also build a culture of co-creation and mutual learning.

Conclusion

Citizen science is a paradigm shift in agricultural research and development. By engaging farmers as co-researchers, it sets field-level knowledge in the spotlight and allows site-specific, adaptive solutions to address urgent concerns such as climate change, pest infestations, and soil erosion.Enabling farmers to watch, test, and collaborate on their knowledge builds ownership and accountability in sustainable agriculture. If supported appropriately, citizen science can be a backbone of participatory, knowledge-based agriculture, leading to food safety, environmental stability, and rural well-being.

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PGR and their role in Vegetable Production

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Plant growth regulators (PGRs) are organic compounds, distinct from nutrients, that influence plant physiological processes when applied in small amounts. They are used directly on plants to beneficially modify their growth processes or structure beneficially, aiming to increase yield, enhance quality, and simplify harvesting. Naturally occurring compounds, known as growth regulators, plant hormones, or phytohormones, play a key role in controlling plant growth. However, when these substances are artificially synthesized, they are called plant growth regulators (PGRs).

Table 1: Plant Growth Regulators and their classes

Plant Growth Regulators	Classes
Auxins	IAA (Indole-3-acetic acid)), NAA (1-Naphthaleneacetic acid), IBA (Indole-3-butyric acid), 2-4D (2,4-Dichlorophenoxyacetic acid), 4-CPA (4-Chlorophenoxyacetic acid).
Gibberllins	Gibberellic acid (GA3)
Cytokinin	Kinetin, Zeatin
Ethylene	Etheral
Abscisic Acid	Dormins, Phaesic Acid

Table 2: Various Plant Growth Regulators and Their Functions

Name of plant growth regulator	Functions	Site of Production
Auxin	(a) Involved in Apical dominance (b) stimulates Cell division and enlargement (c) Shoot and root growth (d) Plant growth movement (e) Parthenocarpy (f) Abscission (g) root induction (h) control fruits drop	Meristem of apical buds, embryo of the seed, young expanding leaves

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Gibberllins	(a) Prevent genetic dwarfism, (b) Regulation in bolting and flowering, (c) Production of parthenocarpic fruit, (d) Germination. (e) Increase flower and fruit size.	Immature seeds
Cytokinin	Cell and organ enlargement (b) Seed germination (c) Development of bud and shoot growth(d) Flower induction (e) Delay senescence	Root apex, endosperm of seeds, young fruits
Ethylene	(a) Ripening of fruit, (b) Seedling growth and emergence, (c) Abscission of leaf.	Ripe fruits, flowers and leaves, and nodes of the stem.
Abscisic Acid	(a) Abscission (b)Maintaining Dormancy (c) Inhibit seed germination and development (d)stimulate stomatal closure	

Auxin: Proposed by Charles Darwin in 1880, auxin was the first plant growth regulator. It promotes cell enlargement, root initiation, and bud formation, and aids in synthesizing other growth hormones. While IAA occurs naturally, NAA, IBA, and 2,4-D are synthetic.

Gibberellic Acid (GA): Discovered by Kurosawa in 1926 from *Gibberella fujikuroi*, GA is synthesized in young leaves, shoots, root tips, and immature seeds. It facilitates seed germination, flower and fruit maturation, cell division, bolting/flowering in long days, and overcoming genetic dwarfism. GA also enhances shelf life, induces male traits in dioecious plants, and increases flower and fruit size.

Cytokinins: Skoog (1955) observed cytokinins' role in promoting cell division and differentiation, nutrient translocation, and bud and root growth. Synthesized cytokinins include BAP, kinetin, and TDZ. Biosynthesis occurs in root tips, seeds, and cambial tissues, moving upward via xylem. They delay senescence and prolong the storage life of flowers and vegetables.

Abscisic Acid (ABA): Known as the stress hormone, ABA inhibits growth, induces dormancy, regulates stomatal closure, and promotes seed protein synthesis. It is synthesized in mature leaves and fruits via pathways involving mevalonic acid or carotenoid decomposition. ABA production increases during genome reprogramming.

Ethylene: Identified by Neljubow and further studied by Denny (1924), ethylene regulates fruit ripening and acts on protein biosynthesis and nucleic acids. It is a natural ripening agent in fruits and increases due to auxin influence.

Role of PGRs in different crops:

Stimulation of Fruit Set: Poor fruit set is a common issue in solanaceous crops. In tomatoes, applying 4-CPA, 2,4-D (2–5 ppm), or PCPA (50–100 ppm) improves fruit set and promotes early development.

Inhibition of Sprouting: To prevent onion sprouting during storage, MH at 2500 ppm is applied 15 days before harvest. For potatoes, soaking tubers in IAA (250–1000 ppm) prolongs dormancy, while thiourea (1%) breaks dormancy.

Flowering: Applying GA at 50 mg/l to young leaves of non-flowering potato varieties during early bud formation induces flowering in all varieties. GA is also effective for early flowering in lettuce, while MH delays flowering in okra.

Seed Germination: Pre-sowing treatment with growth regulators enhances seed emergence. In okra, IAA or NAA at 20 ppm improves germination, while in tomatoes, higher germination rates are achieved with GA3 (0.5 mg/l) or 2,4-D (0.5 mg/l). Soaking seeds in ethephon (480 mg/l for 24 hours) boosts

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germination in muskmelon, bottle gourd, squash melon, and watermelon under low temperatures.

Seed Dormancy: Potato tubers do not sprout until their rest period ends. Dormancy can be broken using GA, ethylene chlorhydrin, or thiourea. Treatment involves exposing tubers to ethylene chlorhydrin vapor (1 liter per 20 q), dipping them in thiourea (1%) for 1 hour, and finally immersing them in GA (1 mg/l) for 2 seconds.

Parthenocarpy: Auxins induce seedless fruits in cucumbers and watermelon. PCPA (50–100 ppm) promotes parthenocarpy in tomatoes and brinjals. Additionally, applying 2,4-D (0.25%) in lanolin paste to style cut ends or as a foliar spray on freshly opened flower clusters has been effective in inducing parthenocarpy

Hybrid Seed Production: Ethephon is widely used to produce female lines in cucurbits. A successful F1 hybrid in butternut squash was achieved through ten weekly ethephon sprays on female lines. Growth regulators are also utilized to maintain gynoecious lines. In cucumbers, GA3 sprays induce staminate flowers in gynoecious plants, while silver nitrate (500 mg/l) is equally effective. In muskmelons, foliar sprays of silver thiosulfate (400 mg/l) have proven most effective for inducing male flowers on gynoecious lines.

Fruit Ripening: Ethephon, an ethylene-releasing agent, facilitates fruit ripening in tomatoes and peppers. Applying ethephon at 1000 mg/l during the turning stage of early fruits accelerates ripening, increasing early yields by 30–35%. Post-harvest dips with ethephon (500–2000 mg/l) also promote ripening in mature green tomatoes.

Plant Growth Regulators play a vital role in contemporary vegetable farming by allowing growers to carefully manage plant growth, development, and output. When used appropriately, PGRs can greatly enhance the yield, quality, and hardiness of vegetable crops, thereby promoting sustainable agriculture and contributing to food security.

References:

Small, C. C., & Degenhardt, D. (2018). Plant growth regulators for enhancing revegetation success in reclamation: A review. *Ecological Engineering*, 118, 43-51

Farman, S., Mushtaq, A., & Azeem, M. W. (2019). Plant growth regulators (PGRs) and their applications: A review. *International Journal of Chemical and Biochemical Sciences*, 15, 94-104. Department of Chemistry, University of Agriculture, Faisalabad-38040, Pakistan

Small, C. C., & Degenhardt, D. (2018). Plant growth regulators for enhancing revegetation success in reclamation: A review. *Ecological Engineering*, 118, 43-51.

Small, C. C., & Degenhardt, D. (2018). Plant growth regulators for enhancing revegetation success in reclamation: A review. Ecological Engineering, 118, 43-51.

Small, C. C., & Degenhardt, D. (2018). Plant growth regulators for enhancing revegetation success in reclamation: A review. *Ecological Engineering*, 118, 43-51.

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Maximizing cropping intensity of a vegetable farm for high income generation

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Smt. KabrabamRanjita Devi aged41 years is W/O K. Rojen Singh who is 47 years old is an enthusiastic farm woman residing at SaitonHayaikon, Bishnupur district of Manipur. She studied upto 10th standard and has two children staying at the hostel of their respective schools. Farming is the only source of income to manage the family expenditure including expenses on herchildren'seducation. She was growing vegetables in an area of about 0.37 ha. Her husband ShriRojen Singh and herself are the only labours for their farm activities. During 2017-18,Shewas cultivating only two crops viz. radish and vegetable rapeseed mustard in her farmdue to lack of scientific knowledge of farming practices. And thereby getting low income of about Rs 62,500/- (Sixtytwo thousand five hundred)only per annum which is insufficient to meet the family expenses and to secure livelihood. One day, she watched a programme on interaction of a progressive farmer with a subject matter expert through U-tube channel of DDK, Imphal. She was inspired by the farmers views and was keen to learn the techniques to cultivate crops and to become a successful farm woman. She approached and met the Subject Matter Specialist – Horticulture in the Krishi Vigyan Kendra, Bishnupur district of Manipur, who guided scientific of cultivating vegetables.

Smt. KabrabamRanjita Devi

With the advise of the SMS- Horticulture, she started the modification of her traditional practices of vegetable cultivation. She attended many training programmes both Short daysand long days Skill development programme conducted by KVK, Bishnupur. She arranged 3- days training programme sponsored by KVK, Bishnupur at her "Vegetable Farm Hut" in order to have the privilege of showing her vegetable growing field to the trainers and trainees. And also to have the demonstration by the Trainers with the motto Seeing is Believing.Through the gained and learned knowledge gained and learned from attending training programmes, she adopted scientific vegetable based cropping system by increasing the

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cropping intensity at her available farm land. She started scientific cultivation of vegetables with improved package of practices formulated by KVK Bishnupur. She could increase the cropping intensity by adopting the proven technologies provided by SMS-Horticulture of the Kendra. Some of the major vegetable crops which are growing in her farm are Vegetable mustard, Radish, Cabbage, Broccoli, Cauliflower, Knolkhol, Broadbean, Okra, Chilli, Brinjal, Potato, Pumpkin, etc.

After 3 years, Smt. Ranjita could earn Rs2,89,500 (Rupees two lakhs eighty nine thousand five hundred only) as annual net income which is about 363% increase over traditional cultivation practices.Now, she has full confidence on selection of high income generating vegetable crops based on the preference of Churachanpur market, Churachanpur district Manipur and the village SaitonHayaikon is the border of Bishnupur and Churachandpur. She was best owed in the recognition of her achievement in the field of horticultural crops by KVK, Bishnupur during the Celebration of Farmers' Day of 2021.Social media viz. DDK Imphal and local newspapers covered her achievements and farm activities. Now she has become a successful farm woman and a role model of the unemployed school dropout Rural youths of her village and also recognized the role and activities of KVK Bishnupur district, Manipur.

- Cropping Intensity during traditional practices :100%
- Cropping Intensity after Scientific intervention :248.6%
- Gross income per annum after Scientific intervention: Rs.3,41,000/-
- Net income per annum after Scientific intervention: Rs. 2,89,500/-
- Benefit CostRatio (B:C) : 6.6 :1

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From Mandis to Mobile Apps: The Digital Evolution of Fodder Sales in Indian Agriculture

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India's agricultural and livestock sectors form the backbone of its rural economy, supporting millions of smallholder farmers and contributing significantly to the national GDP. Within this system, fodder plays a crucial role in sustaining dairy and livestock productivity. However, India faces chronic fodder deficits caused by climatic variability, fragmented supply chains, and market inefficiencies.

In recent years, the rise of digital marketing and e-commerce has begun to transform the agri-input landscape, particularly in fodder sales. By leveraging mobile technology, internet penetration, and innovative platforms, India is pioneering a digital revolution that promises to improve accessibility, affordability, and transparency of fodder inputs. This article explores the evolving digital fodder economy, its impact on farmers and the dairy sector, challenges, and future prospects.

The Importance of Fodder in India's Dairy and Livestock Economy

Fodder resources, including green fodder, dry fodder, and concentrate feed, are essential inputs for maintaining the health and productivity of India's 300+ million cattle and buffalo population (NSSO, 2019). The dairy sector alone contributes around 4.11% to India's GDP and provides livelihoods to approximately 70 million rural households (FAO, 2021).

However, fodder availability is uneven across regions and seasons. The country faces an annual fodder deficit estimated at around 120 million tonnes, exacerbated by climate-induced droughts, shrinking grazing lands, and water scarcity (Singh et al., 2022). Smallholder farmers, who represent the majority of livestock owners, often struggle to access quality fodder at affordable prices, limiting animal productivity and income generation.

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Traditional fodder marketing channels- local mandis, middlemen, and cooperatives- are often inefficient and lack transparency, leading to delays, price distortions, and quality concerns. Geographic isolation and limited market linkages further aggravate these problems in remote rural areas.

Digital Marketing and E-Commerce: Revolutionizing Fodder Sales

The confluence of mobile technology proliferation, affordable internet access, and digital government initiatives such as *Digital India* has paved the way for transformative solutions in agri-input marketing. Digital platforms now enable farmers to directly access, evaluate and purchase fodder inputs, cutting through many traditional barriers.

Emerging Digital Platforms and Marketplaces

Platforms like DeHaat, AgroStar, BharatAgri and several regional startups offer integrated services including e-commerce for fodder seeds, silage additives, processed fodder, and feed supplements. These platforms are increasingly popular among farmers due to:

- **Convenient access** to a wide range of fodder products, often with verified quality certifications.
- **Competitive pricing** through transparent online catalogs and reduced intermediary margins.
- **Advisory services** offering localized recommendations for fodder cultivation and livestock nutrition.

For example, DeHaat reports that farmers using their platform have achieved up to 20% improvement in milk yield due to better feed quality and nutritional guidance (DeHaat Annual Report, 2023).

- **WhatsApp and Micro-Marketing in Rural Communities**

  WhatsApp, with its massive rural penetration, has become a pivotal tool for micro-marketing in fodder sales. Community groups enable farmers to share information on fodder availability, negotiate bulk purchases, and receive extension advice. Local entrepreneurs utilize WhatsApp broadcasts to promote new fodder varieties or feed products.

  This peer-to-peer model fosters trust and reduces information asymmetry-a significant barrier in rural digital commerce (Kumar and Sharma, 2022). Such direct communication channels also allow quick feedback, enhancing product quality and service responsiveness.

- **Enhancing Supply Chain Transparency and Traceability**

  Digital marketing platforms incorporate payment gateways, real-time order tracking, and quality feedback loops. This level of transparency helps farmers verify product authenticity and ensures timely delivery, critical for perishable fodder inputs like silage and green fodder seeds (Patel et al., 2023). It also incentivizes suppliers to maintain quality standards, contributing to overall supply chain efficiency.

Impact of Digital Fodder Marketing on Farmers and Dairy Sector

The digital transformation of fodder input sales has led to numerous positive outcomes:

- **Improved Accessibility and Inclusivity**

  Farmers from remote and marginalized areas now have access to high-quality fodder products previously unavailable to them. Digital platforms have democratized market access by reducing reliance on local intermediaries and physical marketplaces (Singh and Gupta, 2023).

- **Cost Efficiency and Affordability**

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By cutting out multiple layers of intermediaries, e-commerce platforms offer competitive prices. Bulk buying enabled by digital groups lowers per-unit costs, making fodder more affordable for smallholders (Mehta et al., 2022).

- **Enhanced Livestock Productivity**
  Access to scientifically recommended fodder inputs and personalized advisory services helps optimize feed formulations, improving animal health and milk production. Several studies report increased milk yields by 10-25% when farmers adopt digital recommendations (Rao et al., 2021).
- **Farmer Empowerment and Knowledge Dissemination**
  Digital platforms serve as knowledge hubs that educate farmers on fodder cultivation, feed management, and climate adaptation strategies. This empowerment enables farmers to make informed decisions and adopt best practices, creating a positive feedback loop for sustainable dairy farming (Chandra and Singh, 2020).
- **Environmental and Economic Sustainability**
  Efficient fodder use reduces feed wastage and methane emissions from enteric fermentation, contributing to climate resilience. Economic gains from higher productivity and reduced input costs enhance rural livelihoods, supporting sustainable development goals (Sharma et al., 2023).

Challenges and Limitations in Digital Marketing and E-Commerce for Fodder Sales

Despite the transformative potential of digital marketing and e-commerce in India's fodder economy, several significant challenges and limitations hinder the widespread and effective adoption of these technologies by smallholder farmers. These obstacles are multifaceted, spanning technological, socio-economic, and infrastructural dimensions.

- **Digital Literacy and Adoption Barriers**

One of the most profound challenges in scaling digital fodder marketing is the limited digital literacy among smallholder farmers. While smartphone penetration has increased substantially in rural India, many farmers still lack the confidence or skills to navigate complex e-commerce platforms effectively. For instance, the ability to browse product catalogs, compare prices, read reviews, and complete digital payments requires a certain level of familiarity with technology that many farmers, particularly older or less educated individuals, do not possess. Moreover, gender disparities further compound this barrier. Women farmers, who often play a key role in livestock rearing and fodder management, face additional constraints in accessing and using digital tools. Societal norms, limited access to personal devices, lower digital education, and restricted mobility reduce women's participation in digital platforms (Patil and Kumar, 2023). This exclusion not only limits women's empowerment but also constrains overall adoption rates and the reach of digital marketing innovations in rural areas. Addressing digital literacy requires targeted interventions, including tailored training programs, user-friendly app designs in local languages, and community-based digital literacy initiatives that include women and marginalized groups.

- **Infrastructure and Connectivity Constraints**

India's rural internet infrastructure has improved dramatically over the past decade; however, coverage and connectivity remain inconsistent and patchy in many remote and backward regions. High-speed broadband is still largely urban-centric, and rural areas frequently suffer from slow internet speeds, dropped connections, and data cost issues. This unreliability severely impacts the usability of online fodder marketplaces and advisory services that depend on real-time updates and seamless communication. Additionally, frequent power supply disruptions in rural regions further undermine continuous access to digital services. Without reliable electricity, charging devices and maintaining consistent online presence becomes challenging, discouraging regular use of digital platforms. These infrastructural deficits create a vicious cycle where

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limited access reduces user engagement and hinders platform growth. Improving rural digital infrastructure through government investments in broadband expansion, solar-powered charging stations, and affordable data plans is critical to overcoming these challenges (World Bank, 2022).

- **Trust and Behavioural Resistance**

Despite the growing availability of digital platforms, many farmers exhibit skepticism and resistance toward adopting online fodder sales channels, rooted in longstanding dependence on traditional, face-to-face transactions with local traders, cooperatives, and mandis. These conventional sales networks are embedded in social and cultural fabrics, involving personal relationships, credit arrangements, and direct negotiations- elements that digital platforms initially struggle to replicate. Farmers often perceive digital platforms as impersonal or risky, fearing fraud, substandard products, or delayed deliveries. The lack of physical inspection opportunities and unfamiliarity with digital transactions fosters distrust. Moreover, resistance to change is a natural behavioural tendency, especially in communities where innovations are viewed cautiously until proven reliable. Building trust requires localized outreach efforts, including on-ground demonstrations, success stories from peer farmers, training sessions, and government endorsements. Hybrid models combining digital ordering with physical pickup points or trusted local agents can also ease behavioural transitions (Dasgupta et al., 2021).

- **Logistics and Last-Mile Delivery Challenges**

The perishable nature of many fodder inputs, such as green fodder, silage additives, and processed feed, poses significant logistical challenges for e-commerce platforms. Ensuring timely delivery with minimal quality degradation is paramount but difficult to achieve in rural India due to inadequate cold chain infrastructure and fragmented transportation networks. Last-mile delivery- the final stage from warehouse or depot to the farmer's doorstep- is often the most expensive and logistically complex segment. Rural road connectivity issues, scattered farm locations, and a lack of refrigerated transport options limit efficient distribution of perishable products (Singh et al., 2023). These shortcomings result in delayed deliveries, spoilage, and dissatisfied customers, undermining confidence in digital platforms. Developing robust cold chains, leveraging local delivery agents familiar with rural geography, and investing in mobile storage technologies are vital strategies to overcome these obstacles. Public-private partnerships could facilitate infrastructure development and create sustainable logistics models suited to the unique demands of rural fodder distribution.

Policy Implications and Future Directions

To fully harness the transformative potential of digital marketing and e-commerce in India's fodder economy, a comprehensive and coordinated policy framework is imperative. This requires a multi-stakeholder approach, involving government agencies, private sector players, financial institutions, research organizations, and grassroots communities. Firstly, government initiatives must prioritize the expansion of rural digital infrastructure to ensure reliable internet access across underserved regions. This includes not only enhancing broadband connectivity but also providing subsidized smartphones and investing in digital literacy programs tailored to the needs of smallholder farmers. Integrating digital skill development with agricultural extension services can help bridge the digital divide and enable more farmers to engage confidently with online platforms. Secondly, public-private partnerships (PPPs) can play a critical role in building robust, last-mile logistics networks and developing region-specific digital solutions for fodder marketing. These partnerships can leverage private sector innovation and efficiency alongside public funding and outreach to scale up localized delivery models, cold chain systems, and mobile-based advisory services. Promoting financial inclusion is another key pillar. Encouraging the use of digital payment systems, such as UPI and mobile wallets, along with the provision of affordable credit

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products linked to e-commerce transactions, can empower farmers to make timely fodder purchases without cash constraints. Integrating fintech solutions with digital marketplaces ensures greater transaction transparency and builds trust among users. In parallel, research and innovation must be fostered to support the development of new fodder products and technologies, such as silage-based feed solutions, high-nutrient blocks, and climate-resilient forage varieties. Government agencies, agricultural universities, and private innovators should be incentivized to collaborate on Rand D efforts that align with the specific needs of India's diverse agro-climatic zones. Crucially, empowering women farmers is vital for the inclusive growth of the digital fodder economy. Targeted interventions- such as gender-sensitive digital training programs, women-only online forums, and enhanced access to mobile devices and agronomic knowledge-are essential to ensure that women are not left behind in this digital transition. Recognizing and leveraging the central role women play in livestock rearing will not only improve adoption rates but also strengthen food security and rural livelihoods more broadly.

Conclusion

Digital marketing and e-commerce are revolutionizing agri-input sales in India's fodder economy, creating more transparent, efficient, and inclusive supply chains. By empowering smallholder farmers with improved access, knowledge, and choice, these technologies offer a sustainable pathway to enhance dairy productivity and rural livelihoods. Addressing current challenges with focused policy support and innovation will be key to scaling these gains nationwide. As India advances into an increasingly digital future, integrating agri-input marketing with digital ecosystems promises to strengthen food security and resilience in the dairy sector, ensuring that the benefits of technology reach even the most remote corners of the country.

References

Chandra, S., and Singh, R. (2020). Digital literacy and adoption of e-agriculture platforms among smallholder farmers in India. *SAGE Open*, 10(3).

Dasgupta, S., Mehta, A., and Roy, S. (2021). Building trust in digital agri-marketplaces: Insights from rural India. *Emerald Emerging Markets Case Studies*, 11(4).

DeHaat Annual Report (2023). DeHaat: Empowering Indian farmers through digital agri-solutions. Retrieved from ResearchGate database.

FAO (2021). Livestock sector brief: India. Food and Agriculture Organization of the United Nations.

Kumar, V., and Sharma, N. (2022). WhatsApp-based micro-marketing in rural India: A case study of fodder product promotion. *Journal of Rural Development*, 41(2), 159-174.

Mehta, P., Singh, A., and Yadav, R. (2022). Digital interventions for affordable fodder marketing in India: An empirical study. *Journal of Agribusiness in Developing and Emerging Economies*, 12(1), 42-59.

NSSO (2019). Situation Assessment Survey of Agricultural Households in India. Ministry of Statistics and Programme Implementation, Government of India.

Patel, K., Joshi, M., and Desai, S. (2023). Enhancing traceability in agri-input supply chains: Digital tools for fodder marketing. *Computers and Electronics in Agriculture*, 200, 107315.

Patil, S., and Kumar, D. (2023). Gender disparities in digital adoption among Indian farmers: Challenges and opportunities. *Agricultural Economics Research Review*, 36(1), 89-102.

Rao, P., Singh, T., and Mishra, V. (2021). Impact of digital advisory services on fodder management and livestock productivity. *Agricultural Systems*, 190, 103095.

Sharma, R., Jain, A., and Kumar, S. (2023). Sustainable dairy farming and fodder management: Role of digital platforms. *Sustainability*, 15(2), 850.

Singh, H., and Gupta, N. (2023). Digital transformation in Indian agriculture: Opportunities

ISSN: 3049-2289

and challenges for fodder supply chains. *Emerald Insight*, 19(3), 145-162.

Singh, R., Mehta, P., and Kumar, A. (2022). Climate variability and fodder security in India: Challenges and digital solutions. *Journal of Environmental Management*, 304, 114304.

Singh, S., Sharma, P., and Tiwari, R. (2023). Last-mile logistics in agri-input delivery: Emerging trends in digital marketing. *Transportation Research Interdisciplinary Perspectives*, 20, 100796.

World Bank (2022). India Rural Connectivity Report: Digital Infrastructure and Rural Access. The World Bank Group.

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Graph Neural Networks in Soil Carbon Estimation

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Graph Neural Networks (GNNs) are also beginning to show potential as a strong tool for the estimation of soil carbon, overcoming deficiencies of previous methods by accurately capturing spatial relationships and combining multiple environmental data types. Through representing soil sampling points as nodes and spatial or environmental connections among them as edges, GNNs capture intricate patterns affecting Soil Organic Carbon (SOC) distribution. This allows for high-resolution, accurate mapping of SOC even in areas with limited data. Taking advantage of multi-source information including remote sensing, climate, and topography, GNNs provide better prediction performance and scalability, which is a potential game-changer for climate-smart agriculture and global soil carbon monitoring

Soil Carbon and Climate Change: A Global Perspective

Soil has the largest terrestrial carbon sink, holding two to three times more carbon than in the atmosphere of its constituents, Soil Organic Carbon (SOC) is essential for soil fertility, water retention, and ecosystem health. Precise SOC estimation is essential for climate change mitigation, carbon trading, and land management sustainability. SOC distribution, though, is extremely heterogeneous because of soil type, vegetation, land use, topography, and climate, greatly hindering accurate measurement. Conventional techniques like direct sampling, geostatistics, and traditional machine learning do not work well with complex spatial relationships. Remote sensing expands coverage but does not provide accurate spatial context. Graph Neural Networks (GNNs) provide a leap by representing soil sampling locations as nodes and spatial or environmental connections as edges. This method utilizes multi-source data to learn spatial patterns, allowing scalable, precise SOC estimation-even in data-poor areas-boosting climate-smart agriculture worldwide. Zhao, *et.al* 2023.

What Are Graph Neural Networks?

Graph Neural Networks (GNNs) are an emerging category of deep learning algorithms expressly made to work with graph-structured data. Unlike regular neural networks that operate on canonical grids like images (2D pixels) or text (1D sequences), GNNs are particularly well-suited to modeling relational and irregular data, where entities are in non-Euclidean, complex relationships to one another. The central idea of a GNN is the graph, which is formed by nodes (or vertices) and edges. For soil carbon estimation, each node may correspond to a spatial location like a sampling point. The edges between the nodes represent the spatial relationship between the points-geographic distance, slope similarity, or other environmental gradients like elevation or proximity to vegetation. Important Concepts Underlying GNNs.

1. Node Embedding

Each node in a graph contains a collection of features and parameters (e.g., organic matter, temperature, soil pH). GNNs learn abridged vector representations-embeddings-that capture this summary. These embeddings get fine-tuned during training to capture not only the local node features, but also the effect of nearby nodes.

2. Message Passing

The core operation of GNNs is a process known as message passing, wherein a node updates its state by summarizing information from its neighboring nodes. The model can learn contextual patterns through this iterative process since the end representation for a node captures both its own features and the spatial arrangement of nearby regions.

3. Spatial Correlation Learning

One of the strongest features of GNNs is that they can learn spatial relationships directly from data. Rather than relying on pre-specified spatial structures, GNNs adaptively represent how variations in environmental conditions at one point influence surrounding areas. This is especially valuable for modeling and predicting soil organic carbon variability, since it is strongly related to spatial context.

Why Use GNNs for Soil Carbon Estimation?

Soil carbon stocks are shaped by a large number of interacting factors—biological, climatic, and anthropogenic—that in many cases are interdependent in space and time. Conventionally, it is difficult to capture such complicate dependencies jointly, particularly when data are sparse or heterogeneously distributed.

GNNs provide a flexible and robust framework by enabling scientists to:

Model Complex Spatial Dependencies: GNNs are spatial in nature. They can be used to model interdependence over large distances, factoring in the complex geographic and environmental interactions that are lost on simpler models.

Combine Multi-Source Data: GNNs can directly incorporate a broad variety of auxiliary data—e.g., soil characteristics, rainfall regimes, land covers, vegetation indices, and topography—into the model framework. This feature positions them well to build data-dense, context-rich models of soil organic carbon.

Soil Carbon Estimation – The Traditional Approach

Limitations of Conventional Techniques

It has been a long-standing challenge for scientists to estimate soil organic carbon (SOC) with accuracy over large landscapes. Conventionally, researchers and practitioners have used a blend of geostatistical techniques, machine learning algorithms, and remote sensing methods to map and predict soil carbon content. Although these methods have provided useful information, they are also embedded in a range of inherent constraints that limit their ability, especially at larger scales and in intricate landscapes.

Traditional Methods Employed

1. Geostatistics (e.g., Kriging)

Ordinary Kriging, co-Kriging, and regression Kriging are among geostatistical techniques widely used to interpolate soil carbon values between sampling points. These methods rely on the assumption of spatial autocorrelation and apply mathematical models to predict values at unsampled points. Though helpful in well-sampled or small areas, Kriging relies on the stationarity assumption and can be poor when spatial variability is irregular or high.

2.Machine Learning (e.g., Random Forest, SVM, Deep Neural Networks)

Machine learning models are on the increase owing to their potential to capture complex, nonlinear interactions between predictors such as soil attributes, climate, and topography. Random Forest, Support Vector Machines, and Deep Neural Networks are such algorithms that are capable of handling large datasets. They usually approach data as independent samples without explicit spatial dependence modeling.

3. Remote Sensing Coupled with Soil Maps

Indices derived from satellites (e.g., NDVI, Land Surface Temperature) combined with soil maps assist in expanding spatial coverage. These proxies, though, are indirect measures of SOC and require calibration with ground data, which restricts precision.

GNN-Based Soil Carbon Estimation Framework

Since conventional approaches falter to encompass the spatial intricacy of soil carbon dynamics, a graph-based approach based on Graph Neural Networks (GNNs) is a revolutionary method for Soil Organic Carbon (SOC) prediction. The framework combines spatial data, varied environmental variables, and machine learning to better improve the accuracy and scalability of predictions. What follows is a step-by-step explanation of how this graph-based approach functions.

1. Data Collection

Data acquisition is the cornerstone of the whole process with the purpose of collecting both direct soil measurements and ancillary environmental data. Soil sampling points deliver precise, georeferenced SOC values for model training and validation purposes. In addition to this, auxiliary data layers supplement each site with further context. Such layers consist of NDVI, representing vegetation health, DEM data providing elevation and slope information, rainfall and climate records that capture weather patterns, and land use or cover maps that show natural and anthropogenic landscape features. When combined, these varied datasets form a detailed, multi-dimensional profile of every sampling location, increasing the precision and stability of soil carbon estimation.

2. Graph Construction

In constructing a graph, a spatial network is formed whereby each node is associated with a sampling point for soil or a grid cell for an individual location in the landscape. Spatial or environmental relationships between nodes are captured by edges. The connections are usually defined by means such as Euclidean distance, between nodes within a fixed radius, or similarities such as connecting nodes with similar environmental characteristics such as NDVI or rainfall patterns. This technique converts raw data into a location-conscious graph, allowing the model to learn from context and location. Wang *et.al*.2021

3. Feature Assignment

Every node within the graph is allocated an expressive, multi-dimensional feature vector that captures varied environmental traits. These range from intrinsic soil characteristics such as pH, bulk density, and texture, to remote sensing indicators such as NDVI and land surface temperature. Furthermore, elevation and slope topographic characteristics, climatic factors such as temperature and precipitation, and land use classes are included. This varied information facilitates the GNN to learn local soil characteristics together with larger spatial and environmental contexts.

4. Model Training

Once the graph is built and features are associated with every node, a Graph Neural Network (GNN) model-an example of which is a Graph Convolutional Network (GCN) or Graph Attention Network (GAT)-is learned to predict soil organic carbon (SOC).

While training, the model goes through message passing, where nodes communicate with neighboring nodes that they are connected to via edges. This technique allows the model to model rich spatial dependencies and contextual relationships present in the data. Training seeks to reduce prediction error by learning the node representations that effectively capture each node's SOC value. By iterative updates, the model becomes adept at making predictions even at locations that are not sampled. Zhang *et.al.* 2023

5. Prediction

Following training, the GNN model is capable of predicting soil organic carbon (SOC) at unsampled points based on learned spatial connections between nodes. This allows for the creation of continuous, high-resolution maps of soil carbon for large and diverse regions. The model can also be retrained using new data to learn about different regions or integrate other environmental parameters, increasing its accuracy and usability.

Tools and Libraries Used

To apply this graph-based process, there are some recent deep learning frameworks to choose from:

- PyTorch Geometric (PyG): A popular library for constructing GNNs with handy graph manipulation.
- Deep Graph Library (DGL): Scalable GNN creation on various deep learning backends.
- TensorFlow GNN: Google's framework for joining graph learning with TensorFlow.
- Real-World Implementations of GNNs in Soil Carbon Projects

Case Studies and Applications

Graph Neural Networks (GNNs) are gaining strength as an efficient tool in soil carbon estimation based on their distinct capacity to model spatial dependencies and handle multiple environmental data types. Although theoretical accounts are promising, empirical case studies further reaffirm the success of GNNs in applied environmental science. The following are significant instances in which GNN-based solutions have been used to enhance the precision and scalability of Soil Organic Carbon (SOC) estimation.

Example 1: European Soil Carbon Mapping – EU Horizon Project

The European Union's Horizon research initiative has seen an extensive use of GNNs in mapping soil carbon dynamics across varied European landscapes.

- Scope: More than 10,000 geolocated soil sampling sites were utilized, from multiple countries and types of land cover.
- Integration of Data: Topography, land use, satellite imagery (Sentinel-2 NDVI), and climatic data were integrated as node features in a graph space.

Performance Gain:

GNNs showed an improvement of 15% in R^2 (coefficient of determination) compared to baseline machine learning models such as Random Forests.

The model depicted cross-boundary spatial patterns and outperformed grid-based models in transition zones and ecotones.

Example 2: Indo-Gangetic Plains Pilot Study – India

In India, a pilot study was carried out over the Indo-Gangetic Plains—one of the planet's richest but data-variable areas.

- Data Fusion: The study combined MODIS-derived NDVI, rainfall data sets, digital elevation models (DEM), and proximate soil laboratory data.
- Graph Structure: Soil sampling locations served as nodes, joined by distance-weighted edges to represent spatial proximity.

Model Outputs:

The GNN resulted in spatially smooth and ecologically coherent SOC maps, even in data-poor districts.

It recorded a 20% decrease in Root Mean Square Error (RMSE) over baseline models.

The method was especially powerful in separating low SOC zones devastated by erosion and overuse.

Other Applications of GNNs for SOC Estimation

Aside from mapping, GNNs are being considered for various forward-looking applications:

- Predicting SOC Under Land Use Change: By modeling how spatial land use changes (e.g., deforestation, urbanization) influence SOC stocks, GNNs enable the prediction of long-term soil carbon trends.
- Restoration and Rehabilitation Planning: In degraded or desertified areas, GNNs may be used to select possible carbon sequestration areas through examination of past and spatial contexts.
- Policy Effect Monitoring: If combined with satellite observations and administrative records, GNNs are able to quantify the carbon effect of agricultural and environmental policy through time.

Advantages of GNNs Over Other Methods

The correct estimation and delineation of Soil Organic Carbon (SOC) has proved to be a difficult task for researchers over the years because of the intricate and heterogeneous character of soil landscapes. The conventional approaches such as geostatistics and traditional machine learning (ML) models have performed well, but they lose out on utilizing the complete range of spatial and contextual data. This is where Graph Neural Networks (GNNs) come into play as a game-changing technology in digital soil mapping.

Major Strengths of GNNs

1. Spatial Learning: Embracing Topological Dependencies

Whereas traditional grid-based models or general ML algorithms work with the data points as separate entities, the GNNs explicitly represent the spatial relations via graph structures. This implies the effect of nearby sampling points, the similarity of terrain, or similar land use patterns can be easily incorporated into the learning process.

2. Scalability to Large and Complex Datasets

GNNs are designed to process graph-structured data, making them ideal for working with massive, complex spatial datasets. Whether it's national soil inventories or global satellite archives, GNNs scale efficiently, offering consistent performance.

3. Generalizability to Unseen Regions

One of the most significant benefits of GNNs is their generalization to new geographies that were outside the training dataset. Since they learn deep spatial patterns instead of surface patterns, GNNs can make strong predictions in under-sampled or new geographies.

4. Multi-Source and Multi-Scale Data Integration

GNNs incorporate disparate and multi-modal inputs in a seamless manner, including soil lab data, topography, remote sensing indices (e.g., NDVI), land use data, and climate variables. This integrated modeling scheme makes sure that local soil conditions as well as large-scale environmental trends are taken into account.

Overcoming the Challenges of GNN Implementation

Limitations and Challenges

Whereas Graph Neural Networks (GNNs) present revolutionary potential for soil carbon estimation, their translation into real-world soil observation and digital agriculture applications is accompanied by a number of limitations. Being aware and solving these constraints is imperative for guaranteeing strong and scalable implementation of GNNs in soil science applications.

Important Challenges

Graph Neural Networks (GNNs) offer advanced capabilities for modeling spatial data like soil organic carbon (SOC), but face key limitations. First, GNNs require rich, spatially coherent SOC and auxiliary datasets, which are often sparse or misaligned. Transfer learning and institutional data-sharing can mitigate this. Second, graph construction is complex, requiring careful definition of edges and node features—best addressed through expert input and adaptive algorithms. Third, training on large, high-dimensional graphs demands substantial computing power. Efficient GNN variants and cloud-based solutions help reduce costs. Finally, GNNs lack interpretability; explainability tools and hybrid models enhance transparency.

Path Forward: Overcoming the Barriers

Challenge	Proposed Solution
Data Scarcity	Transfer learning, data sharing networks
Graph Construction	Domain knowledge integration, adaptive edge modeling
High Computation	Lightweight GNNs, GPU/cloud use, sampling methods
Lack of Interpretability	Post hoc analysis tools, hybrid interpretable models

Future Prospects and Conclusion

Towards AI-Driven Soil Carbon Monitoring

The future of soil carbon estimation is poised for transformation through advanced AI techniques like Graph Neural Networks (GNNs). Emerging trends point toward real-time soil organic carbon (SOC) monitoring by integrating GNNs with edge AI and sensor networks, enabling dynamic updates on soil health. Furthermore, coupling GNN-based SOC models with blockchain technology can revolutionize carbon trading by ensuring transparent and verifiable carbon credits. Integration with climate models will enhance predictive power, allowing better forecasting of soil carbon responses to environmental changes.

Conclusion

GNNs represent a cutting-edge approach that captures the complex spatial dependencies inherent in soil systems. By providing more accurate, scalable, and spatially aware SOC estimations, GNNs support climate-smart agriculture and sustainable land management. With continuous improvements in data availability and computational infrastructure, GNN-driven frameworks hold great promise to be deployed globally, helping mitigate climate change while enhancing soil fertility and ecosystem resilience.

References

Li, P., Hao, H., Zhang, Z., Mao, X., Xu, J., Lv, Y., ... & Ge, D. (2022). A field study to estimate heavy metal concentrations in a soil-rice system: Application of graph neural networks. *Science of the total environment*, *832*, 155099.

Wang, R., Mou, S., Wang, X., Xiao, W., Ju, Q., Shi, C., & Xie, X. (2021, April). Graph structure estimation neural networks. In *Proceedings of the web conference 2021* (pp. 342-353).

Zhang, Z., Li, Y., Bai, Y., Li, Y., & Liu, M. (2023). Convolutional graph neural networks-based research on estimating heavy metal concentrations in a soil-rice system. *Environmental Science and Pollution Research*, *30*(15), 44100-44111.

Zhao, W., & Efremova, N. (2023). Soil organic carbon estimation from climate-related features with graph neural network. *arXiv preprint arXiv:2311.15979*.

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Battery-Powered Systems in Indian Agriculture: A Pathway to Sustainable Mechanization

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Agriculture remains a vital sector in the Indian economy, employing nearly 52% of the workforce and contributing approximately 15% to the national Gross Domestic Product (GDP) as of 2016–17. Over the years, significant transitions have occurred in the power sources used for farming activities. Traditionally dependent on animal power, the sector has increasingly adopted mechanical and electrical sources. By 2016–17, the share of mechanical and electrical power sources had risen from just 7.7% to 90.12%, indicating a profound mechanization shift.

Despite these developments, the spread of farm mechanization in India has been uneven. Variations in regional infrastructure, landholding patterns, and farming practices have significantly influenced the pace and extent of technology adoption. The primary aim of mechanization is to increase productivity, enhance efficiency, and reduce reliance on manual labor by deploying modern agricultural equipment. Yet, various systemic issues including fragmented landholdings, a high proportion of small and marginal farmers, limited financial resources, unfavorable environmental conditions, and diverse topographies pose persistent challenges (Jat et al., 2016) and (Mehta et al., 2019)

Traditional tools and animal-based systems are insufficient for the modern demands of agriculture. These methods often fail under high workloads or adverse conditions, delivering limited outputs. While fossil fuel-powered machines have improved efficiency, they also contribute significantly to greenhouse gas (GHG) emissions and environmental degradation. The growing awareness of issues like fossil fuel depletion, GHG emissions, and climate change has intensified the need for alternative energy sources. In response, battery-powered systems have emerged as a promising solution to reconcile the dual goals of productivity and sustainability in agriculture.

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Scope of Battery Power in Agriculture

Battery-powered systems are gaining momentum in agriculture, largely due to their high energy efficiency nearly three times greater than that of conventional internal combustion engines (ICEs) (Patel et al., 2021). They offer numerous ecological advantages, including the absence of harmful emissions such as sulfur oxides, nitrogen oxides, and polycyclic aromatic hydrocarbons. This makes them particularly suitable for use in various agricultural settings, including open fields, nurseries, greenhouses and vineyards.

In an era marked by rapid population growth and climate uncertainty, the modernization of agricultural machinery is imperative. Battery-powered equipment, as demonstrated in multiple case studies, can help address these challenges effectively. A strategic policy focus on encouraging on-site renewable energy production such as solar-powered charging infrastructure could further support farmers in adopting this technology. The integration of battery power is not limited to agriculture. These systems are already in use in urban transportation, airports, railway stations, parks, and zoos. Their benefits include instant torque, quick response, superior energy conversion rates, and fewer mechanical parts, which lead to lower maintenance and operational costs. When used in agricultural machinery, battery-powered motors offer additional advantages: they consume no energy while idle and can be efficiently employed in low-speed operations common in smallholder farming (Singh et al.,2019).

Direct current (DC) motors with gear reduction drives are typically preferred in such settings. Among them, brushless DC motors are favored due to their higher efficiency, longer lifespan, and minimal maintenance needs compared to brushed alternatives. However, the use of lead-acid batteries can raise operational costs due to their limited life cycles and long charging times. Despite this drawback, the application of DC motors powered by batteries in agriculture has the potential to significantly reduce physical labor, enhance productivity, and minimize environmental impacts. Choosing between batteries and solar panels for powering agricultural machinery depends on local conditions, costs, and operational needs. Both offer viable alternatives to fossil fuel-based systems, particularly when paired with efficient motors and gear systems tailored to the demands of Indian smallholders (Singh et al., 2019) and (Pandey et al., 2023).

Advantages of Battery Power in Sustainable Agriculture

Battery-powered systems offer multiple benefits that align with the goals of sustainable agricultural development. These advantages span environmental, economic, and operational dimensions:

1. **Environmental Sustainability**
   Battery-powered agricultural equipment emits zero direct emissions during operation. This leads to a substantial reduction in GHG emissions, contributing to improved air quality and a healthier ecosystem (Kumar et al., 2020). Reduced pollution also benefits public health, particularly in rural areas with high agricultural activity.

2. **Noise Pollution Reduction**
   Electric agricultural machinery operates significantly more quietly than ICE-powered equipment. This is beneficial in farming regions near residential areas or environmentally sensitive zones, helping reduce noise-related disturbances for both humans and wildlife.
3. **Higher Energy Efficiency**
   Electric motors used in battery-powered machinery convert a greater portion of stored energy into useful mechanical work. This reduces energy wastage and results in lower operational costs over time (Singh & Verma, 2019).
4. **Compatibility with Renewable Energy Sources**
   Batteries can be charged using renewable sources such as solar or wind energy. This integration not only enhances sustainability but also fosters energy independence by reducing reliance on fluctuating fuel supplies.
5. **Reduced Operating Costs**
   While initial investments in battery-powered equipment may be higher, they are offset by lower energy costs. Electricity is generally cheaper and more price-stable than diesel or petrol, leading to economic benefits over the equipment's lifetime.
6. **Support for Precision Agriculture**
   Modern battery-powered systems often come equipped with advanced features such as GPS guidance, variable rate technology, and automation. These tools enhance precision in input application, minimize waste, and improve crop yield outcomes.
7. **Versatility and Modularity**
   Battery-powered machines can be adapted for a wide range of agricultural tasks, including seeding, tilling, spraying, and harvesting. Modular battery systems offer flexibility, allowing farmers to customize machinery according to their needs.
8. **Low Maintenance Requirements**
   With fewer moving parts and the absence of oil or fuel systems, battery-powered machinery generally requires less maintenance. This translates into reduced downtime and repair costs.
9. **Improved Durability**
   Advancements in battery technologies have led to longer-lasting batteries, thereby decreasing replacement frequency and associated disposal concerns. Lithium-ion and other advanced battery types are particularly promising in this regard.

Limitations and Challenges

Despite their many benefits, battery-powered agricultural systems face certain limitations that hinder their widespread adoption:

- **Energy Storage Capacity**
  Current battery technologies offer limited storage, which can restrict operating hours. Frequent recharging is necessary, which may disrupt continuous farming operations.
- **Battery Cost and Life Span**
  High upfront costs and concerns over battery degradation are major barriers. Replacing batteries after a few years adds to operational expenses, making it difficult for small and marginal farmers to afford.
- **Charging Infrastructure**
  The lack of widespread charging stations, especially in remote rural areas, poses logistical challenges. Establishing reliable and accessible charging networks is essential for broader adoption.
- **Temperature Sensitivity**
  Battery performance can decline in extreme temperatures, which may affect their efficiency and reliability during certain seasons or in specific regions.

However, ongoing research is addressing these concerns. Innovations in high-energy-density batteries, such as solid-state and lithium-sulfur batteries, are promising. Fast-charging technologies and improved thermal management systems are also being developed to extend battery life and reduce downtime.

Conclusion

Battery-powered agricultural machinery represents a transformative opportunity for Indian agriculture. These systems address critical challenges associated with labor shortages, environmental degradation, and the need for sustainable intensification of food production. By reducing physical strain on farmers, enhancing operational efficiency, and curbing pollution, battery-powered technologies align well with the broader goals of sustainable development. Nevertheless, several barriers must be overcome to ensure widespread adoption. The high cost of batteries, limited energy storage, and lack of infrastructure are significant hurdles. Government policy, industry innovation, and academic research must converge to support the development and deployment of affordable, durable, and high-performance battery systems for agriculture. Future research should prioritize the advancement of battery technologies that offer faster charging, higher energy densities, longer life spans, and minimal environmental impact. Integration with renewable energy systems such as solar-powered charging should be explored to further improve sustainability.

In conclusion, battery-powered systems are not merely an alternative to traditional mechanization they are a necessary evolution. With the right policy support and technological innovation, they can enable India's agricultural sector to transition toward a cleaner, more efficient, and sustainable future.

References

Jat, R. A., Saharawat, Y. S., & Gupta, R. (2016). Conservation agriculture in cereal systems of South Asia: Nutrient management perspectives. Karnataka Journal of Agricultural Sciences, 29(1), 1–8.

Mehta, C. R., Chandel, N. S., Jena, P. C., & Jha, A. (2019). Indian agriculture counting on farm mechanization. Agricultural Mechanization in Asia, Africa and Latin America, 50(1), 84–89.

Patel, H. R., Rana, M. S., & Panchal, M. K. (2021). Electrification of farm machinery: Status and prospects. Indian Farming, 71(6), 15–19.

Singh, S. P., Utpal, E., Singh, M. K., & Pandey, H. S. (2019). Electric prime mover: A need for smallholders in India. International Journal of Innovations in Engineering and Technology, 13(4), 131–136.

Singh, M. K., Singh, S. P., Singh, M. K., & Utpal, E. (2019). Battery assisted four-wheel weeder for reducing the drudgery of farmers. Indian Journal of Agricultural Sciences, 89, 1434–1438.

Pandey, H. S., Tiwari, G. S., & Sharma, A. K. (2023). Design and development of an e-powered inter row weeder for small farm mechanization. Journal of Scientific & Industrial Research, 82(6), 671–682.

Kumar, P., Singh, D. K., & Sharma, S. K. (2020). Battery operated farm machines: A solution towards sustainable agriculture. Journal of Agricultural Engineering, 57(2), 45–53.

Singh, Y., & Verma, K. K. (2019). Renewable energy-powered agricultural machinery: A review. International Journal of Agricultural Science and Technology, 7(3), 23–30.

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Smart Fertilizer Recommendation: A DSS-Based Framework for Sustainable Agriculture

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Fertilizer use in agriculture must strike a balance between enhancing crop productivity and protecting environmental health. Conventional methods, often based on uniform application rates, fail to address spatial variability in soil and crop needs, leading to inefficiencies and environmental stress. Decision Support Systems (DSS) provide an innovative approach by integrating data such as soil test values, crop nutrient requirements, climate, and management history to generate tailored recommendations. This assignment explores the concept of DSS in fertilizer management, outlines its objectives, describes its functional components, and highlights widely used tools in India. It also discusses the key benefits, practical challenges, and future directions, emphasizing the increasing role of emerging technologies like AI, IoT, and cloud computing in improving decision-making. DSS are increasingly vital in promoting precision agriculture and sustainable soil fertility management.

The optimization of fertilizer application in agriculture stands as a pivotal challenge, demanding sophisticated strategies to enhance crop yields while minimizing environmental consequences. Traditional fertilization practices often rely on uniform application rates, neglecting the inherent variability in soil properties, crop nutrient requirements, and microclimatic conditions within a

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field (Musanase et al., 2023). This can lead to over-fertilization in some areas, causing nutrient runoff and pollution, and under-fertilization in others, limiting crop growth and yield potential (Thompson et al., 2018). Decision support systems offer a promising avenue for addressing these challenges by providing farmers and agricultural advisors with data-driven recommendations tailored to specific field conditions. By integrating diverse data sources, such as soil analysis, weather patterns, crop growth models, and real-time sensor data, these systems can generate precise fertilizer recommendations that optimize nutrient use efficiency, reduce environmental impact, and enhance profitability.

What is Decision Support System?

A Decision Support System (DSS) for fertilizer recommendation is an advanced, software-driven platform developed to support farmers, agronomists, and agricultural planners in making scientifically sound and efficient decisions regarding the application of fertilizers. These systems integrate multiple layers of information—including soil test results, crop nutrient requirements, climatic conditions, and historical management practices—with analytical models and expert knowledge bases. By processing these diverse data inputs, the DSS generates site-specific, crop-sensitive fertilizer recommendations that aim to optimize yield, reduce input costs, and minimize environmental impact. Such systems are especially valuable in precision agriculture, where tailored nutrient management plays a critical role in improving sustainability and productivity (Thompson et al., 1997). Moreover, the integration of Geographic Information Systems can significantly enhance the capabilities of DSS by enabling spatial data management and visualization (Su & Wen, 2001).

Objectives

- To provide site-specific nutrient management
- To enhance fertilizer use efficiency
- To support sustainable soil fertility management.
- To reduce input costs and maximize returns
- To minimize environmental impacts
- To promote data-driven agricultural practices:

Key Components

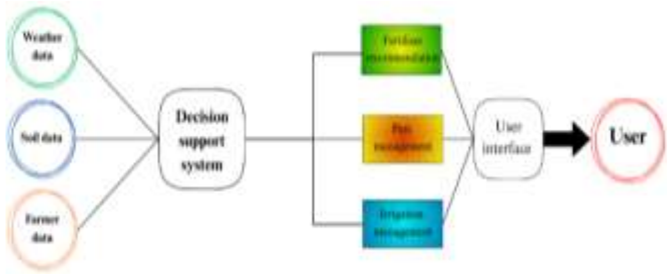

Fig.1. Key components of Decision Support System

Popular Fertilizer DSS Tools in India

Table .1. Some popular DSS Tools used in Agriculture

DSS Name	Developed By	Purpose / Key Feature	Application Area
Nutrient Expert	CIMMYT & IPNI	Site-specific nutrient management (SSNM) for maize, wheat, rice	South Asia
NEFMS	ICAR	Nitrogen management in rice and wheat	India
SHC DSS	Govt. of India	Fertilizer advice based on Soil Health Card data	Nationwide (India)
FARMS DSS	ICRISAT	Fertilizer recommendations using land, rainfall, cropping data	Semi-arid tropics (India, Africa)
Crop Manager	IRRI	Mobile-based nutrient and crop advice	Philippines, Bangladesh, India
Krishi Gyan Sagar	ICAR	Crop, pest, and fertilizer advisory	India
GeoFert DSS	ICAR-IISS	GIS-based geo-referenced fertilizer recommendation	Precision farming zones in India

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Working Mechanism

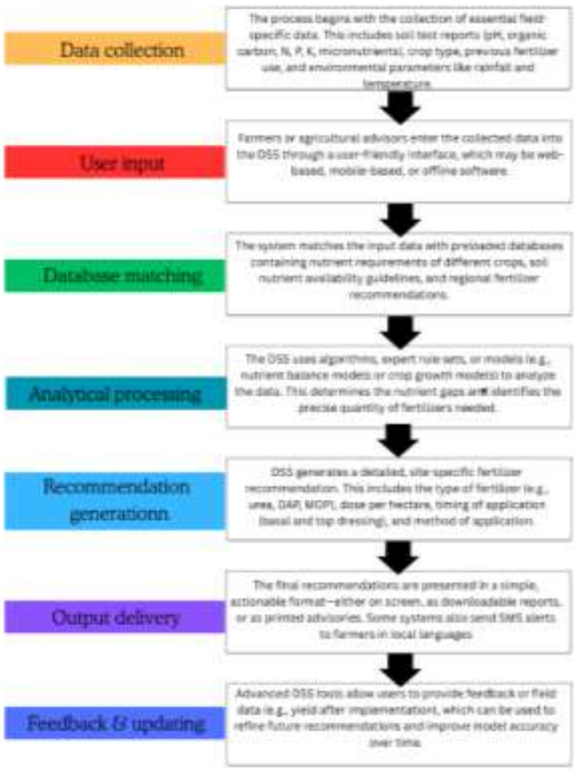

Fig.2. Flowchart of complete working mechanism

Benefits

Decision Support Systems in agriculture provide substantial benefits by integrating information to aid farmers in making informed decisions for crop production (Kanatas et al., 2020). They reduce production costs, enhance productivity, and promote sustainability by matching manufacturing plans effectively (Kaushik & Bhardwaj, 2013). DSSs collect data related to climatic conditions, crop growth parameters, and the presence of pests to rank a list of suitable treatments (Kanatas et al., 2020). Furthermore, precision water and fertilizer application technologies substantially improve crop yields, enhance resource efficiency, and reduce environmental impacts, marking significant advancements in sustainable agricultural practices (Xing & Wang, 2024).

Table .2. Benefits of using DSS Tools

Benefit	Explanation
Site-Specific Advice	Provides tailored fertilizer recommendations for individual field conditions.
Improved Nutrient Use Efficiency	Ensures better utilization of applied fertilizers.
Cost Saving for Farmers	Reduces over-application and waste, lowering input costs.
Higher Crop Yield	Enhances productivity through balanced nutrient supply.
Balanced Nutrient Application	Avoids nutrient deficiencies and toxicities in the soil.
Reduced Environmental Impact	Limits runoff and leaching, helping protect soil and water.
Data-Driven Decision Making	Integrates soil data, crop requirements, and expert models for accurate output.

Challenges

Table .3. Potential limitations of Decision Support System tools

Challenge	Description
Data Availability	Reliable, up-to-date soil and crop data are often missing or incomplete.
Farmer Awareness & Training	Many farmers are unaware of DSS tools or lack training to use them effectively.
Connectivity Issues	Internet and digital infrastructure are limited in remote agricultural areas.
Localization Difficulty	Customizing DSS for diverse agro-climatic zones is complex and resource-heavy.
Integration with Existing Systems	Poor alignment with local practices and tools limits adoption.
Cost and Maintenance	Development and upkeep of DSS software can be expensive for institutions.
Language and Interface Barriers	Lack of multilingual or user-friendly interfaces hinders wide-scale use.
Limited Real-Time Feedback	Many systems do not offer dynamic, real-time updates based on changing data.

Future Directions

As agriculture moves towards greater precision and sustainability, the future of Decision Support Systems (DSS) in fertilizer recommendation is poised for transformative growth. Traditional DSS tools, once limited to static datasets and basic algorithms, are now evolving with the integration of cutting-edge technologies such as artificial intelligence (AI), machine learning, Internet of Things (IoT), and real-time data analytics. These advancements promise to make DSS more adaptive, predictive, and personalized, delivering dynamic nutrient management solutions that respond to real-time field conditions, weather changes, and crop growth stages. Furthermore, mobile accessibility, cloud computing are enhancing the reach, reliability, and transparency of these systems. As digital infrastructure expands, the next generation of DSS will play a central role in empowering farmers with smarter, faster, and more sustainable fertilizer recommendations across diverse agro-ecological zones.

Table .4. Future aspects of DSS based agricultural system

Aspect	Future Potential
AI & Machine Learning Integration	Enable predictive, adaptive, and self-learning nutrient recommendations.
Real-Time Weather-Based Advice	Provide dynamic fertilizer schedules based on rainfall, temperature, and humidity.
Mobile & Voice-Enabled Platforms	Improve accessibility for farmers through smartphones and voice-assisted tools.
IoT-Based Soil Sensors	Collect real-time field data to fine-tune recommendations instantly.
Cloud-Based Advisory Systems	Centralized storage and processing to support region-wide DSS access and updates.
Expanded GIS Integration	Enable spatially referenced fertilizer mapping for precision agriculture.

Conclusion

Decision Support Systems have emerged as essential tools in modern agriculture, particularly for managing fertilizer application more efficiently and sustainably. By utilizing diverse datasets and expert models, these systems provide field-specific guidance, helping farmers apply the right nutrients at the right time and in the correct amounts. Several DSS platforms in India already demonstrate the benefits of improved yields, reduced costs, and minimized environmental impact. However, certain challenges remain—such as limited data availability, user training needs, and the demand for better digital infrastructure. Looking ahead, the integration of real-time technologies like artificial intelligence, GIS mapping, and sensor-based feedback will make DSS even more responsive and scalable. These advancements are set to redefine nutrient management, making it more precise, data-driven, and adaptable to local farming conditions.

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Turning Waste into Wealth: Value Addition in Fruits and Vegetables

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India, the second-largest producer of fruits (102.76 million tonnes) and vegetables (196.26 million tonnes) after China, leads globally in crops like banana, mangoes, lime, lemon, papaya, and okra (NHB, 2022-23). Yet, its contribution to the food processing industry remains a modest 1.3%. Fruits and vegetables, rich in energy, body-building nutrients, vitamins, and minerals, are highly perishable, leading to significant postharvest losses due to inadequate handling, distribution, marketing, and storage facilities. Value addition—transforming produce into more desirable forms like jams, jellies, pickles, squash, and preserves—extends shelf life, reduces waste, and enhances economic value and consumer appeal. This article explores how processing technologies can convert perishable and underutilized produce into shelf-stable, nutrient-rich products, addressing food security and economic opportunities.

Need for Value Addition

Fruits and vegetables are prone to spoilage, making preservation critical to ensure year-round availability and minimize losses from harvesting to consumption. Processing extends shelf life beyond peak seasons, preventing glut and utilizing surplus produce. Value addition enhances economic value by transforming raw produce into products that meet consumer preferences for convenience, nutrition, and flavor. Postharvest technologies, evaluated for technical, economic, and social impacts, are increasingly central to agricultural research, focusing on reducing waste and improving utilization.

Unlocking the Potential of Minor Fruits

Minor fruits, such as jackfruit, palmyrah palm, karonda, chironji, and amra, are often less palatable than mainstream fruits and are grown with minimal inputs, earning names like underutilized, less appealing, or wild fruits. Despite their limited commercial cultivation, these fruits are rich in health-promoting compounds and have acceptable sensory profiles. Processing minor fruits into value-added products like jams, beverages, and pickles offers significant opportunities for enhancing their market value and reducing waste.

Technologies for Value Addition

Various processing techniques, including dehydration, freezing, packaging, and labeling, enhance the value of horticultural produce. These methods preserve quality, extend shelf life, and improve marketability. Below are key value-added products and their preparation methods:

Beverages

Beverages, fermented or unfermented, sweetened or unsweetened, are popular value-added products. Unfermented ready-to-serve (RTS) beverages, made from fruit and vegetable juices with added sugar, water, and additives, are valued for their nutritional content, refreshing quality, and medicinal properties (Rathinasamy *et al*., 2021). Blending astringent or bitter fruits with others enhances flavor, nutrition, and shelf life. Examples include RTS beverages from grapes, gooseberries, litchi, pineapple, and orange, often enriched with whey protein (e.g., orange and watermelon blends) to boost nutritional value and act as appetizers. Banana pseudostem juice, rich in antioxidants like gentisic acid and catechin, can be blended with other juices to enhance sensory and nutritional profiles.

Processed Products

- Bael: Pulp is used to make nectar, squash, toffee, and powder (Pandey *et al.,* 2008).
- Ber: Processed into murabba, candy, dehydrated ber, pulp, jam, and RTS beverages.
- Jamun: Transformed into fermented and non-fermented beverages, jelly, jam, and leather.
- Karonda: Ideal for pickles, jams, candies, chutneys, beverages, and osmo-air dried or canned products (Srivastava *et al.,* 2017).
- Guava: Processed into juice, sauce, dumplings, jelly, puree, fruit bars, and canned products. Guava jelly, made from strained juice, is preserved with sodium benzoate for extended shelf life

Guava Jelly Preparation

To prepare guava jelly, whole guava fruits are washed, peeled, and cut into small pieces. One kilogram of fruit is blended and filtered to yield 700 ml of juice. The juice is heated at 160°C for 10 minutes until boiling, then mixed with 300 g sugar, 0.2 g citric acid, 0.3 g sodium chloride, and 0.02 g sodium benzoate, with water added to reach 1 liter. The mixture is stirred, combined with 10 g thickener and 5 drops of guava flavor, heated, cooled, and packaged (Cho *et al*., 2021).

- Wild Apricot

Wild apricots (chulli), with high acidity and low sugar, are unsuitable for fresh consumption but ideal for processing into jams, chutneys, and alcoholic beverages like wine, vermouth, and brandy (Sharma *et al*., 2014). Osmotic dehydration is used as a pre-treatment for drying low-quality apricots (Rahman, 2007). Apricot-soy products like leather, toffee, and fruit bars, as well as wine and mead, are prepared by diluting pulp, adding di-ammonium hydrogen phosphate, pectinol, and fermenting with Saccharomyces cerevisiae (Sharma *et al.,* 2014).

- Ginger

Fresh ginger, valued for its aroma and pungency from compounds like gingerol and zingiberone, is perishable and susceptible to spoilage. Value-added products include ginger oil, oleoresin, candy, preserve, puree, powder, beer, paste, and soft drinks like cordial and ginger cocktail. Ginger leather, prepared by dehydrating puree into leathery sheets, and salted ginger, made from tender rhizomes soaked in salt and citric acid, are novel products (Govindarajan and Connell, 1983).

These products enhance shelf life and market value.

- Jackfruit

Unripe jackfruit is processed into chips, pickles, brined products, and ready-to-cook items, while half-ripe and ripe jackfruits are used for candies, jams, jellies, leathers, nectar, and canned products (Srivastava *et al.,* 2017). For example, jackfruit chips are made by blanching slices, drying at 60–70°C, and frying at 160°C. Jackfruit candy involves blanching,

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treating with calcium lactate and potassium metabisulphite (KMS), and steeping in increasing sugar syrup concentrations. Ripe jackfruit pulp is used for jams, leathers, and nectar, with bulbs canned in sugar syrup for extended shelf life.

Jackfruit Candy Preparation

Half-ripe jackfruit is cut into 1×0.5×0.5 cm³ pieces, blanched at 95°C for 4 minutes, treated with 2% calcium lactate and 0.1% KMS, and steeped in sugar syrup (25–70°Brix) over 12-hour intervals. The pieces are drained, washed, dried at 70°C to 10% moisture, and packaged in polypropylene pouches (Srivastava *et al.,* 2017).

Jackfruit Jam and Leather

Jam is made by boiling ripe jackfruit pulp with 700 g sugar and 10 g pectin per kg, adding 0.25% citric acid, and cooking to 64°Brix. Rind jelly uses 1 kg rind boiled with 1.5 liters water and 2 g citric acid, with 700 g sugar added to reach 65°Brix. Leathers are prepared by boiling pulp with 10–15% sugar and 0.1 g/kg KMS, drying at 60°C for 20 hours to 20% moisture, and cutting into pieces (Srivastava *et al.,* 2017).

➢ Karonda

Karonda fruits, both unripe and ripe, are processed into candies, jams, pickles, chutneys, beverages, syrups, osmo-air dried products, and canned items. Karonda candy involves blanching unripe fruits in potassium metabisulphite and steeping in 60–70°Brix syrup. Jams use ripe fruits boiled with sugar to 68–70% TSS, leveraging high pectin content (Srivastava *et al.,* 2017). Pickles are made by curing crushed fruits with salt for 30 days, mixing with spices and oil (Davison, 2018). Karonda juice, blended with guava or pineapple, enhances organoleptic quality. Syrup is prepared by boiling ripe fruits with baking soda and sugar, concentrating to half volume.

Challenges in Value Addition

Despite its potential, value addition faces hurdles like:

- Policy Gaps: Lack of policies supporting growers' limits adoption.
- Quality Regulation: Inconsistent standards affect product quality.
- Infrastructure Shortages: Insufficient processing units and preservation facilities hinder scalability and export potential.

Conclusion

Value addition transforms perishable and underutilized fruits and vegetables into shelf-stable, nutrient-rich products, reducing postharvest losses and enhancing economic returns. By leveraging processing technologies like dehydration, canning, and beverage production, India can boost its food processing industry, meet consumer demand for functional foods, and align with FAO/WHO recommendations for a 400 g daily intake of fruits and vegetables (WHO, 2020). These efforts not only ensure food security but also create opportunities for rural employment and sustainable agriculture.

References

Cho, K. M., & Lwin, H. H. Comparative Study on Nutritional Values and Some Physicochemical Properties of Jelly Prepared from Psidium guajava (Guava).

Davison, J. (2018). *Pickles: A global history*. Reaktion Books.

Govindarajan, V. S., & Connell, D. W. (1983). Ginger—chemistry, technology, and quality evaluation: part 1. *CRC critical reviews in food science and nutrition*, *17*(1), 1-96.

Pandey, D., Shukla, S. K., & Pandey, G. (2008). Bael (Aegle marmelos Correa). *Underutilized Horticultural Crops*, *3*, 201-224.

Rathinasamy, M., Ayyasamy, S., Velusamy, S., & Suresh, A. (2021). Natural fruits based ready to serve (RTS) beverages: a review. Journal of Food Science and Technology, 1-7.

Srivastava, A., Bishnoi, S. K., & Sarkar, P. K. (2017). Value addition in minor fruits of eastern India: an opportunity to generate rural employment. *Fruits for Livelihood: Production Technology and Management Practices. Agrobios (India), Jodhpur, India*, 395-417.

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Glacier for Life: Securing our shared sustainable future

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The imperative of glacier conservation emerges as a significant focal point in the international dialogue of sustainable water resource management. It is high time to highlight the essential function that glaciers serve in supplying freshwater to billions of individuals and the pressing necessity to confront their accelerated melting as a consequence of climate change. Glaciers, commonly known as "water towers," are essential in supplying freshwater to billions of individuals. They function as natural reservoirs, holding water in its solid state and slowly releasing it in the warmer months. This function is especially crucial for areas that rely on glacial meltwater for farming, drinking, and their purpose. The preservation of glaciers has emerged as a critical imperative for the vitality of ecosystems and the endurance of human populations globally. Glaciers serve as important indicators of climate change, playing a key role in the stability of water resources, climate control, and the preservation of biodiversity. The swift melting and retreat of these ice formations due to rising global temperatures pose a significant risk to established ecological and hydrological systems, highlighting the need for immediate conservation efforts. Glaciers are currently experiencing unprecedented changes in their mass and extent. Research suggests that smaller glaciers could diminish more rapidly than their larger equivalents because of their increased area-to-volume ratio, making them more vulnerable to rising temperatures (DeBeer & Sharp, 2009).

By examining the climatic factors affecting glacier dynamics, many studies in high altitude asian region have recorded a steady increase in runoff driven by both glacier melt and alterations in precipitation patterns. Moreover, the acceleration of ice loss across regions such as the Himalayas over the past four decades provides a stark illustration of this linkage (Maurer *et al*., 2019). The heavy thinning recorded in clean-ice glaciers, in contrast to their debris-heavy counterparts, showcases the intricate responses of various glacier types to elevated temperatures. These distinctions are crucial not only for forecasting future melting patterns but also for addressing the related risks, such as glacier lake outburst floods (GLOFs).

The rise in glacier melting has direct consequences for water supply in critical river systems. This reliance on streams fed by glaciers highlights the urgent need for the preservation of glacier health. Forecasts suggest that areas dependent on glacier runoff from monsoon seasons, like the Ganges and Brahmaputra basins, could see peak water flows by 2050, followed by a troubling decrease in runoff due to glacier loss (Rounce *et al.*, 2020).

- **Glaciers and its forms**

Glaciers, magnificent natural phenomena formed from the accumulation and compaction of snow over decades and centuries, are classified into several distinct types based on their characteristics, behaviour, and underlying processes. Understanding these classifications is crucial for recognizing their roles in Earth's climate system, ecosystem dynamics, and hydrology. One of the type of glaciers are Valley glaciers, also known as alpine glaciers, which are confined within valleys typically formed by glacial erosion, flowing primarily due to gravity and adapting to the topography they occupy. Found in mountainous regions such as the Rocky Mountains and the Himalayas, they shape landscapes and provide vital meltwater for ecosystems and human consumption. Outlet glaciers, which are a subset of valley glaciers, flow out of ice caps or ice sheets and into oceans or other glaciers, often exhibiting rapid flow rates and calving behaviour that contributes to sea-level rise. These outlet glaciers of the Greenland Ice Sheet serve as significant indicators of climate change. There are also the Ice sheets, the largest type of glacier which cover vast land areas and play a crucial role in global climate regulation, with the Greenland and Antarctic Ice Sheets holding approximately 68% of Earth's freshwater. Ice caps, smaller than ice sheets, cover less than 50,000 km^2 and typically exhibit a dome shape, releasing meltwater that sustains surrounding ecosystems. Another type of glaciers are the Surge-type glaciers which exhibit unique periodic surges, where they shift from slow movement to rapid acceleration, sometimes increasing velocities up to 1,000 times their normal speed. Though they constitute less than 1% of all glaciers, they are vital in understanding glacier dynamics, with surge mechanisms driven by either thermal switching or hydrological changes. Lastly, Rock glaciers contain a mixture of ice and rock debris, moving at much slower rates and serving as important buffers in high-altitude environments by gradually releasing meltwater. Their movement is influenced by interannual climatic variability, making them valuable indicators of climate change in alpine regions. Together, these glacier types illustrate the diverse and dynamic nature of Earth's cryosphere, highlighting their significance in shaping landscapes, supporting ecosystems, and influencing global climate patterns.

- **Key Statistics: The Accelerating Retreat of Glaciers**

According to the IPCC Sixth Assessment Report (2021), glaciers in both polar and mountain regions are retreating at an unprecedented rate. Among these The Alps, Himalayas, and Andes are most affected by glacier loss. It further stated that if the current trend continues the glaciers in The Himalayas could lose more than 50% of their volume whereas the Andes and Alps could lose up to 70% and 80% respectively, by 2100. IPCC Special Report on the Ocean and Cryosphere (2019) highlighted that glaciers worldwide have been losing 0.85 meters per year, of mass for over a century. The Himalayas have lost 30% of their mass since the 1970s, The Andes lost between 30% to 50% of their ice volume whereas the Alps lost 1 to 2 meters per year, while Greenland Antarctica contributed about 0.2 mm per year to global sea- level rise.

Due to global warming, glaciers are melting at an unprecedented rate, with an average loss of 267 billion metric tons of ice per year since 2000, contributing to approximately 21% of observed sea level rise. In the Himalayas, glacier melt contributes up to 50% of river flow during dry seasons, and its decline could lead to widespread water scarcity. The economic and ecological impacts of glacier loss are profound, as they support hydropower generation, which accounts for 16% of global electricity production, and sustain fisheries and agriculture vital for food security.

- **Innovative Solution to Mitigate Glacier Crisis**

The rapid melting of glaciers due to climate change demands innovative solutions to preserve these vital resources. Traditional approaches alone are insufficient to address the scale of the problem. Here are some innovative solutions being developed and implemented globally to tackle glacier preservation, along with real-world examples **(Fig. 1):**

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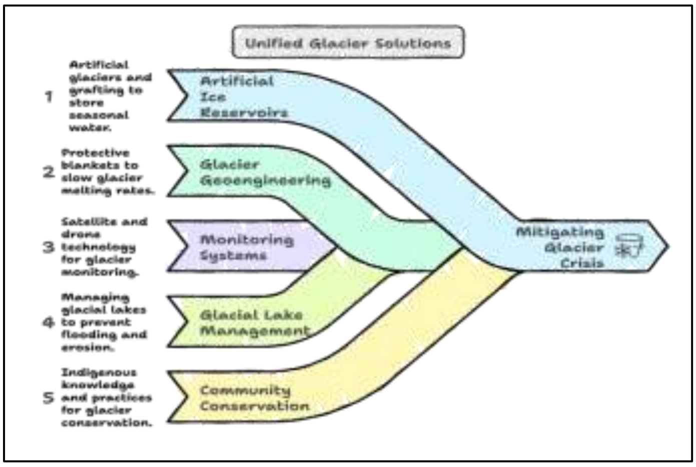

Fig.1: Innovative Solution to Mitigate Glacier Crisis

1. Artificial Ice Reservoirs (AIRs): Dry mountain environments of Central Asia or the Andes directly rely on the seasonal meltwater for their farming and drinking needs (Unger-Shayesteh *et al.*, 2013; Chen *et al.*, 2016; Buytaert *et al.*, 2017; Apel *et al.*, 2018; Hoelzle *et al.*, 2019). Glacier melt and snowmelt are the only sources of water supply for the region experiencing low annual rainfall (Thayyen and Gergan, 2010). This leads communities to relocate. Therefore, AIRs are constructed to store water in the form of ice. It is typically built during the cold winter and designed to slowly release freshwater during the warm spring and summer months, serving the main purpose of irrigation. Around, 26 villages in the Ladakh region have been using AIRs to adapt to climate change-related Glacier melt (Wangchuk,2021).

a) Ice Stupas (Artificial Glaciers): Ice structure also known as Ice stupa, named after the Buddhist shrines, uses the natural flow of water which freezes in sub-zero temperatures to form conical shaped ice domes with wire mesh and branches provided to give support to the structure (**Fig. 2**). Due to the conical shape of the domes, the lowest possible surface area is exposed to the outside temperature during summer, providing a slowly melting and long lasting artificial reservoir (Geneletti & Dawa, 2009; Chopra, 2017; Clouse, 2017).

b) Glacier Grafting: Glacier grafting is a traditional practice followed by local communities of the upper Indus Basin in Ladakh (Gagné 2016; Nüsser and Baghel 2016) and various locations in Northern Pakistan (Schmidt and Nüsser 2017) and villages of Gilgit-Baltistan. It includes the breeding of Male glaciers identified by their black colour, covered in soil and rocks with the Female glaciers typically of a white or bluish colour, at a high altitude of 1200 feet in the mountains (Munir *et al.*,2021). The locals take packs of glacial ice and containers carrying Indus River water placing them in caves and covering them with the soil. This ice melts slowly during the summer and is used to fulfil their needs. This ancient technique stands as an important source of water supply.

Fig 2: An Ice Stupa in Ladakh accumulates ice from a sprinkler-like system (K Lyons, 2023)

2. **Glacier Geoengineering:** Studies on climate change is increasingly focusing on the role that geoengineering plays in reducing global warming. Geoengineering is positioned as a "unconventional approach" that complements the "conventional" approaches to adaptation and mitigation of climate change. The idea of geoengineering is gradually being applied to glacier preservation as well, given the significant role that glaciers play in the climate system.

a) Protective Blankets (Geotextiles): According to Larocca *et al.* (2024), the glaciers' snowline exhibits a positive association with annual temperature, which causes the glacier volume to decrease and upsets the mass and energy balance. Therefore, protecting alpine glaciers necessitates both artificially increasing glacier albedo and lowering greenhouse gas emissions to minimize temperature increases. For this, the majority of studies suggest micro-engineering based on geoengineering mechanisms (**Fig. 3**). Glacier melt can be minimized and glacier loss can be slowed down quickly by covering the glacier surface with geotextiles (Olefs & Lehning, 2010; Fischer *et al.*, 2016; Senese *et al.,* 2020). Instead of melting ice surfaces, geotextiles' high albedo reflects more shortwave solar radiation. Because of their superior thermal qualities and semi-permeable nature, which

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inhibits water pooling and lessens the warming effect of percolating water, they decrease melt caused by turbulent heat fluxes (Fisher *et al*., 2016).

Fig.3: Geotextile cover on Presena Ovest Glacier in summer 2010 (Senese et al., 2020)

3. Advanced Monitoring and Early Warning Systems: An Early Warning System (EWS) provides advance alerts to communities downstream of glacial lakes, allowing them to take precautions and reduce potential damage and loss of life during a GLOF event. It consists of monitoring systems, communication networks, and dissemination platforms. Monitoring systems track key indicators such as lake levels, water temperature, and seismic activity. Remote sensing tools like satellite imagery and aerial photography can provide valuable insights into the condition of the moraine dam and the size and volume of the glacial lake. Communication networks play a crucial role in ensuring that warnings reach the affected populations, utilizing channels like radios, television, mobile phones, and sirens. These communication networks must be accessible to all community members, regardless of their socioeconomic status or location. Several countries have successfully implemented EWS for GLOFs which has significantly reduced the impacts of GLOFs through its integrated system of monitoring, communication, and dissemination (Pandey *et al*., 2021).

a) Satellite and Drone Technology: Satellite and drone technologies are increasingly being used for monitoring glaciers, offering significant advantages in terms of precision, accessibility, and efficiency. Satellite technology provides a broad, global perspective, enabling the monitoring of glaciers from space. Satellites equipped with remote sensing instruments can capture high-resolution images and data on glacier size, ice flow, and changes in surface elevation. This data can be used to track long-term trends in glacier dynamics, such as retreat or advance, and to assess the impacts of climate change on glaciers (Khadka *et al*., 2020; Wang *et al*., 2020). Drone technology, on the other hand, allows for more localized and detailed observations. Drones can fly closer to glaciers, capturing high-resolution imagery and video footage of specific regions that may be difficult to reach by traditional methods. They can be equipped with various sensors to measure ice thickness, surface temperature, and other critical data (**Fig. 4**).

Fig.4: GPS and spectral reflectance measurements (Rossini et al., 2023)

4. *Glacial Lake Management:* The melting of glaciers has led to the formation and expansion of numerous glacial lakes, creating a growing threat of glacial lake outburst floods. The Himalayas are considered one of the most climate-change-vulnerable regions in the world (Westoby *et al*.,2014) and the growth of glacial lakes in the area has amplified the risk of glacial hazards, including Glacial Lake Outburst Floods (Nei *et al*.,2018). GLOFs frequency has increased in recent years due to the climate change as a result of global warming but careful management of Glacier Lake can help prevent a catastrophe. Glacial lake management is critical for minimizing flood risks, adapting to climate change, protecting ecosystems, managing water resources, ensuring safety, and maintaining the cultural and tourism value of these unique landscapes.

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5. Community-Led Conservation or Indigenous Knowledge and Practices: Indigenous communities have indeed practised sustainable adaptation principles for generations, as they have been developing their own customary knowledge so as to understand just how to best change to a changing future climate (Suarez, 2020). According to research, deforestation rates are twice as low in areas where Indigenous people have land rights compared to similar areas without time, showing Indigenous communities' strong grasp of their environment (Suarez, 2020). These communities have actively participated in community-based tree planting initiatives for raising of awareness about the importance of forest conservation and the need for planting of new trees. Tribes have also, notably decreased their reliance on forest wood by switching over to renewable energy sources for their daily needs, contributing to a protection as well as preservation of forests coupled with the broader environment (Sethi *et al*.,2024). The UN Climate Change Learning Partnership's (UNCC:Learn) collaborative initiatives generally have recognized that Indigenous peoples often possess revolutionary ideas and valuable knowledge for the real safeguarding of biodiversity and the important promoting of ecological conservation (Sethi *et al.,* 2024).

- **The Road Ahead**

The road ahead for glacier conservation involves a combination of mitigation, adaptation, research, and global cooperation. Government must intervene promptly by implementing effective policies aimed at the source of Glacier detoriation and International agreements must be strengthened in a bid to have concentrated effort in reducing the impact of climate change on the Glaciers. Public awareness and education efforts are equally important, involving local communities in preservation strategies, engaging youth in climate action, and promoting sustainable tourism practices to minimize environmental impact. Individuals can take practical steps in everyday life to reduce their carbon footprints, one of the key causes of fast melting of glaciers. Establishing conservation areas, regulating industrial activities, and enforcing sustainable tourism guidelines can help protect glacial regions from further degradation. A long-term vision for glacier preservation must recognize intergenerational responsibility, integrating it into broader climate action, biodiversity conservation, and sustainable development goals. Preserving glaciers demands immediate and collective action, ensuring the sustainability of these vital ice masses for future generations.

- **Conclusion**

This World Water Day 2025, let us take a moment to appreciate the inalienable value of glaciers, for they are not mere expanses of ice but precious lifelines for billions of human beings around the world. Glaciers supply freshwater, stabilize ecosystems, and help maintain environmental balance. They must be saved, not just because they are vital water sources, but also because their disappearance will have significant consequences on water security globally, on agriculture and industry, and on human welfare in general. The journey ahead for glacier preservation is challenging but not insurmountable. It requires a coordinated global effort, innovative solutions, and a commitment to sustainable practices. By acting now, we can slow the rate of glacier retreat, protect ecosystems, and ensure a stable water supply for future generations. The preservation of glaciers is not just an environmental issue—it is a matter of global survival and equity.

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From Diversity Comes Prosperity: A Farmer's Success Story

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Farming everywhere is subjected to various types of risks and uncertainties. These risk may be human induced or may be result of natural calamities. In a country like ours where farming is dominated by the presence of marginal and small farmers, such type of risk threatens the farm sector as well as communities engaged in this noble profession. Calamities like insect-pests and diseases, untimely rainfall, hailstorms, fast blowing winds result in considerable loss of yields ultimately making agriculture a non-remunerative profession. Agriculture is not only confined to crops or livestock. Agriculture encompasses a wide range of enterprises which among others also include goatry, sheep, apiculture, sericulture, piggery, floriculture, horticulture, olericulture etc. Continuing with a single enterprise runs the risk of ruining the fortunes of farmers in case any calamity struck the fields and results in devastation of crops. We need to have approaches which ensure a regular income for the farmers even in case of failure of one crop/enterprise. One such approach is to have more than one enterprise or produce more than one product to avoid having your income totally dependent on the production and price of one product.

Farmer enterprise diversification is a strategy that involves increasing the variety of crops, livestock, or activities on a farm to reduce risk and increase economic gain. It can also involve using existing resources in new ways, such as processing raw materials on the farm. If profit from one product is poor, profit from producing other products may prevent total profit from falling below acceptable levels.

This is what is called as enterprise diversification. Enterprise diversification is a self-insuring strategy used by farmers to protect against risk (Mishra et al, 2004). Having more than one enterprise ensures that farmer gets compensated from one of the enterprises in case of failure of other. In fact, enterprise diversification is a self-insuring strategy used by farmers to protect against various risks. Promoting a Farming System Approach through Integrated Farming System IFS models is the

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best way towards enterprise diversification. In this paradigm, the output of one enterprise becomes input of other enterprise thereby helping in reduction of cost of cultivation and increased profit. More over the resources within the farm are judiciously used contributing to the sustainability of the system.

Enterprise diversification in farming offers numerous benefits, making it a highly effective strategy for farmers-

1) **Risk management:** By diversifying their businesses, farmers can share the risk of illnesses, pests, market swings, and climate change, resulting in more steady revenue streams.
2) **Increased Income:** Farmers can increase overall profitability by generating numerous revenue streams through a variety of agricultural activities, including crop cultivation, animal raising, and value-added processing.
3) **Resource Optimization:** Diversification makes it possible to use land, labour, and capital more effectively, which boosts farming enterprises' sustainability and efficiency.
4) **Enhancement of Soil Health:** Combining different crops and livestock can improve the fertility and structure of the soil, lessen erosion, and encourage sustainable farming methods.
5) **Market Opportunities:** Diversified farms provide access to a variety of markets, such as specialist and niche markets, which frequently have lower competition and larger profit margins.
6) **Climatic Change Resilience**: Farmers can better adapt to climatic unpredictability and extreme events by diversifying their crops and livestock, which increases their resistance to unfavourable weather conditions.

Success stories of farmer enterprises

i. **Mushroom cultivation**

Mr Ghanshyam Prasad after several discussions and technical guidance of KVK experts and ATMA, he was motivated to start mushroom cultivation. He started his entrepreneurship with 10 kg oyster mushroom spawn which was purchased from BAU Sabour. It was inoculated in 100 bags hanging in a thatched roof of 150 square foot during November 2012. He successfully grew 60kg mushroom in his first attempt and sold 40 kg as fresh @ Rs. 150/ kg. Balance 20 kg of the produced mushroom was converted in to pickles which was further sold out. In the first attempt he realized the net profit of Rs. 4500 and got confidence of production and marketing. In the second attempt, he produced 150 kg of fresh mushroom and got the net profit of Rs. 10000. After third round during 2012-13, he earned a total earning of Rs. 30000. Further, he produced mushroom throughout the year and assured the spawn availability for the nearby farmers. In addition, he converted mushroom waste along with buffalo dung and other agricultural wastes into vermi- compost by which his crop on the 5 ha land yielded higher. With his zeal, now, Mr. Ghanshyam has become not only a role model among unemployed rural youth of his village.

ii. **Prosperous Dairy Farming through Crossbreeds in Karnal**

The Arvind Dairy Farm in Nalvi Khurd village, Karnal, Haryana was initiated as an integrated livestock within a traditional agriculture farming system through the efforts of Mr. Pramod Khokhar. Mr. Ravi Khokhar wanted to change the family-based subsistence farming system to

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rearing crossbred dairy cows in order to diversify the farming. He underwent training at National Dairy Research Institute (NDRI) before starting Arvind Dairy Farm. He owns well-fed healthy crossbred cows and an automated milk collection system, well-maintained cattle shed and a feeding area. Currently, Arvind Dairy also has 30 crossbred cattle, and the milk is marketed to the nearby areas. The farm has also sold around 50-60 animals and currently has 80 percent dairy animals in the lactating phase. The peak yield of cattle ranges from 35-53 litres. Animals are fed a mixture of green and dry fodder consisting of berseem or oats and wheat straw thrice a day, along with some homemade concentrate (maize/wheat/barley + de-oiled cake + neembola) and a mineral mixture (200 gm per day per animal) for good health and quality milk. Proper and timely vaccination is followed in order to maintain the sound health of the animals. Mr. Ravi follows NDRI's guidelines as per which there should be 13-14 months calving interval among cattle. He credits the success of Arvind Dairy Farm to hard work and passion. As a result of this dedication, the farm has expanded from 30 to 80 crossbreeds with proper modern facilities for dairy animals.

iii. Vinay Kumar from Bihar:
Vinay Kumar transformed his 10-acre farm into a highly profitable enterprise by adopting modern techniques, organic practices, and innovative sugarcane cultivation. His diversified approach, which includes rice, wheat, coarse grains, fruits, and fish farming, results in an annual profit of 20 lakh rupees.

iv. Nagaraj Nakhat from Bihar:
At 76 years old, Nagaraj Nakhat revolutionized farming in his region by cultivating dragon fruit. Starting with just 100 plants, he expanded to over 17,000 plants across 7 acres, increasing production from 1 to 50 metric tons in six years. His farm now generates millions and inspires other farmers to adopt smart farming practices.

v. Shivaji Rajput from Maharashtra:
Shivaji transformed 25 acres into a sustainable bamboo plantation, earning significant profits. Starting with just 100 plants, he now manages a thriving bamboo farm that supports his family and the local economy.

Conclusion

Farmers' success through business diversification demonstrates the value of creativity and flexibility in conquering obstacles. Farmers may improve their standard of living and support rural development by utilizing market trends, integrating value chains, and cultivating strategic alliances. Diversification can be a sustainable route to economic and agricultural success if resources are available and policies are supportive.

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The hidden giant: The world's largest living organism is an underground

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Hidden beneath Oregon's Blue Mountains lies the world's largest known living organism, not an animal or a tree, but a fungus called *Armillaria ostoyae*. Discovered in 1998, this vast network spans over 2,384 acres, forming a single, genetically identical life form that's thousands of years old. Often called the "Humongous Fungus," it exists mostly underground as mycelium, with only seasonal mushrooms visible above. While it plays a vital role in forest ecosystems by decomposing organic matter, it can also act as a harmful pathogen, killing trees. Its discovery challenges our understanding of life's scale and complexity and may offer insights into ecosystem resilience, forest health, and the hidden networks that support life on Earth.

When we think of the largest living things on Earth, blue whales and towering redwood trees usually come to mind. But surprisingly, the largest living organism isn't something you can easily see, and it's neither an animal nor a tree. Hidden beneath the soil in Oregon's Blue Mountains lies a giant fungus known as Armillaria ostoyae. This massive organism extends over 2,300 acres, making it larger than 1,600 football fields. What's visible above ground, the mushrooms, is only a small, temporary part of it. The real organism consists of a vast network of white, thread-like mycelium that feeds on dead wood and plant matter. Genetically, it is all one connected life form, estimated to be over 8,000 years old. Its immense size, age, and ecological role as a decomposer make it one of the largest, most important, and oldest living organisms known to science.

DISCOVERY

In 1998, a team of forestry scientists set out to study a tree-killing disease in eastern Oregon. What they uncovered was far more surprising: a single fungal organism, spreading invisibly beneath the soil for miles. Through DNA testing and sample matching, the team discovered that seemingly separate mushroom patches were part of the same genetic individual. This discovery crowned *Armillaria ostoyae* as the largest known living organism on the planet.

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THE HUMONGOUS FUNGUS

Armillaria ostoyae is often referred to as the "Humongous Fungus," is a type of honey mushroom. However, the mushrooms you might see peeking above the forest floor are just the tip of the iceberg. These are merely the fruiting bodies of a much larger organism. The true giant lies underground, a vast network of white, thread-like filaments called mycelium. These threads weave through the soil, feeding on dead plant matter and tree roots. This organism extends a staggering 2,384 acres (965 hectares) in Oregon's Blue Mountains, which is much larger than a blue whale. Genetically identical across its entire reach, this organism functions as one single life form, making it not only the largest by area but also one of the most biologically fascinating.

EXPANSION, SURVIVAL, AND AGE

The fungus spreads by extending hyphae, tiny filaments that release digestive enzymes to break down wood and other plant material. Uniquely, it can also grow rhizomorphs—dark, root-like structures that stretch across the soil to find new food sources. This gives the organism the ability to reach far beyond a single tree or stump, bridging gaps between nutrients and extending its underground network. Scientists estimate that this fungal network is between 2,400 and 8,650 years old. This ancient life form has witnessed centuries of change above ground, storms, seasons, wildfires, and yet continues to grow silently below.

A DOUBLE-EDGED ROLE IN NATURE

While this giant fungus plays an essential ecological role, it also has a darker side. As a decomposer, it helps maintain forest health by breaking down dead wood and recycling nutrients back into the soil. This keeps the forest floor rich and fertile, supporting the growth of new plants and trees. However, *Armillaria ostoyae* is also a pathogen. It causes Armillaria root disease, which kills conifer trees by attacking their roots. In some parts of the U.S. and Canada, large areas of forest have been damaged by its spread. While it's a natural part of many ecosystems, it can become destructive when conditions allow it to dominate.

Figure 2: Dark honey mushrooms emerging at the base of a tree indicate infection by Armillaria ostoyae
Credit: Arterra/Universal Images Group via Getty Images.

A FUNGUS FESTIVAL

This isn't the only massive fungus to fascinate scientists. In 1992, a similar species, *Armillaria gallica*, formerly known as *Armillaria bulbosa,* was found covering 37 acres in Crystal Falls, Michigan. That smaller, less harmful cousin of Oregon's giant is now celebrated annually at the town's "Fungus Fest," where locals embrace their unique underground neighbor with pride. Both examples reveal that fungi can reach astounding sizes and offer valuable lessons about biology, ecology, and evolution.

LOOKING AHEAD

As research into fungi and mycelial networks continues, *Armillaria ostoyae* could provide valuable insights into climate resilience, forest management, and biodiversity. Mycologists and ecologists alike see potential in understanding how such organisms maintain cohesion and stability over thousands of years. Its survival may even offer clues about how ecosystems adapt and recover from environmental stress, knowledge that's increasingly important in an era of climate change and habitat destruction.

CONCLUSION

The story of *Armillaria ostoyae* shows us that the biggest and most powerful living things aren't always the ones we can see. It's quiet, steady growth reminds us that not all amazing life forms are loud or visible. This "humongous fungus" is a hidden wonder, showing how much we still have to learn about the world beneath our feet. It could even help scientists understand how forests survive and adapt as our planet changes.

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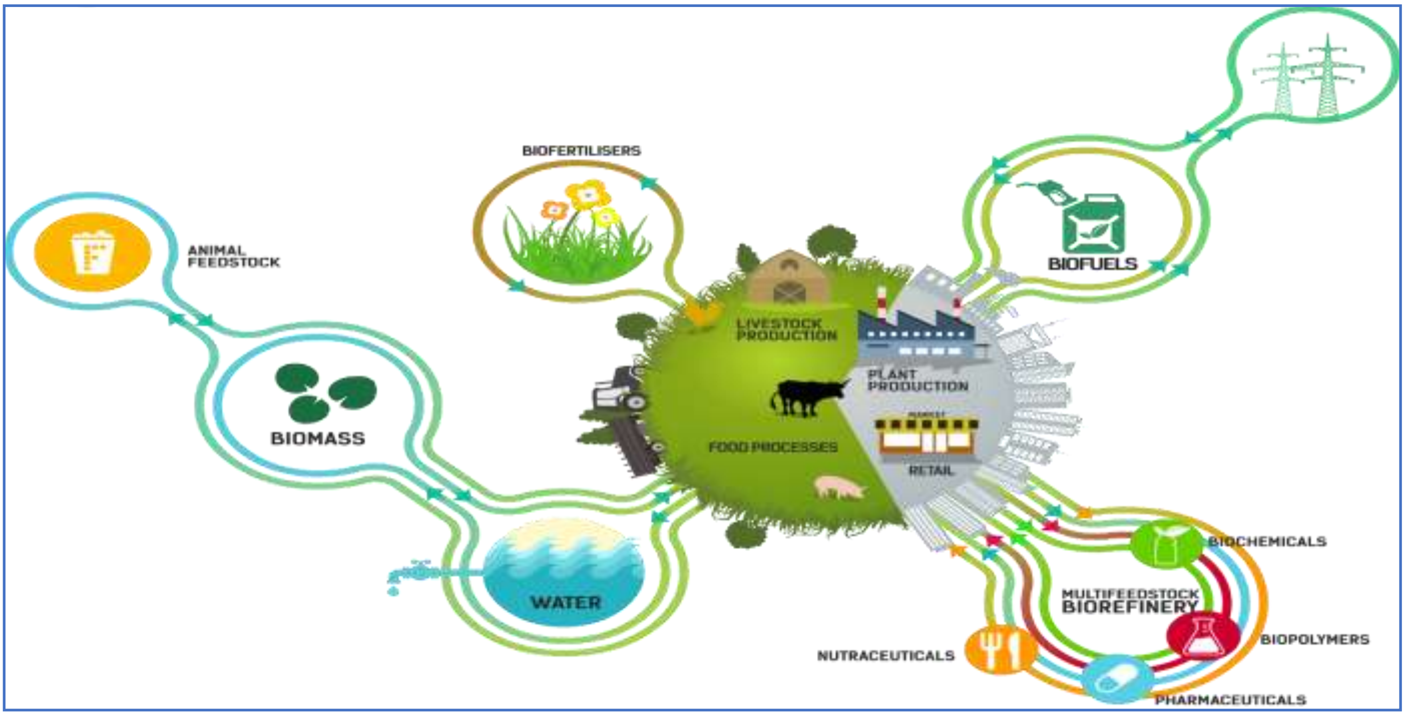

Unlocking the Value From Food Waste

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The rapid population growth and increasing urbanization have driven up the demand for food, resulting in a significant rise in the need for processed foods. Consequently, the food processing industry is expanding faster than most other industries, leading to substantial waste generation. A significant portion of this food waste occurs during harvesting, manufacturing, handling, storage, processing, distribution, and consumption. Consequently, in a circular economy, waste valorization entails the creation of valuable goods like chemicals, materials, and fuels. It improves the economy, society, and environment in addition to creating value-added products like organic fertilizers, animal feed, biofuels, and power from food waste.

a. **Food Loss**

The Food and Agriculture Organization of the United Nations (FAO) defined food loss as any change in the availability, edibility, wholesomeness or quality of edible material that prevents it from being consumed by people. The post-harvest period of food, which ends when it is in the hands of the final consumer, is covered by this term.

Food waste

‘‘Any food, or inedible portions of food, that is taken out of the food supply chain and recovered or disposed of, including composting, planting unharvested crops, anaerobic digestion, producing bioenergy, cogeneration, incineration, disposing of it in a landfill or sewer, or discarding it into the sea).

1.1 Understanding the Scale of the Issue

Before delving into solutions, it's essential to understand the scale of the food waste problem. Food waste occurs at every stage of the supply chain, from farm to fork. In developed countries, the majority of food waste occurs at the consumer level, driven by factors such as over-purchasing, improper storage, and cosmetic standards. In contrast, in developing countries, food loss is more prevalent during production, post-harvest handling, and transportation due to inadequate infrastructure and technology. Regardless of where it occurs, food waste represents

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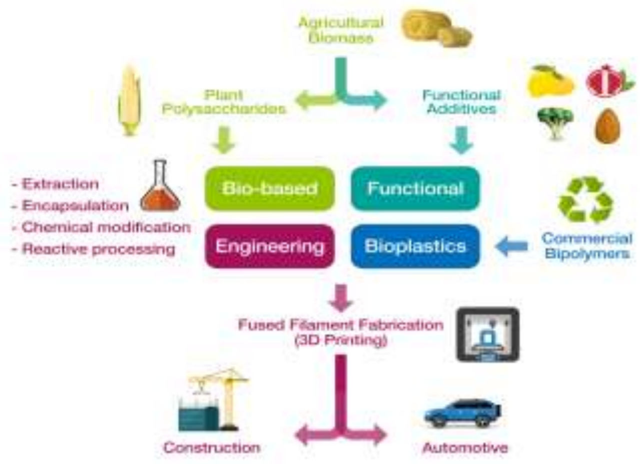
a loss of resources, including water, energy, labor, and land, with significant economic and environmental implications.

1. **SOURCES OF FOOD WASTE**
   - Plant derived
   - Animal derived
   - Food Industry derived
   - Restaurant derived

1. **Plant derived food waste :**
   Plant based food waste mainly consist of fruits, vegetables waste i.e., peels, seeds, pomace etc and other agricultural based food waste. Food waste derived from agricultural goods has been reported as a potential bio-toolkit for soil improvement due to the inclusion of numerous nutrients. Plant food waste is the rich source of bioactive compounds and they may be utilized for the production of numerous of pharmaceuticals and nutraceuticals.
2. **Animal based food waste:**
   Animal food waste is also high generating waste which mainly includes bones, animal hair, hides and organs. They are rich in good quality proteins and also utilized for the production of different protein based products.

Food Industry derived

Food waste streams are largely composed of byproducts from the food and organic waste sectors. Various nutrients and bioactive substances can be found in food waste streams that come from the food industry.46, 47, 69 Sources of vital minerals and nutrients include fruit juice, cheese production, and brewing, among other food-related enterprises. In the food waste streams of major food companies, such as those involved in the processing of potatoes, cereals, fish, and fruits, the most commonly discovered nutrients and useful chemicals are carbohydrates, cellulose, hemicellulose, proteins, lignin, pectin, lipids, and antioxidants. It also contains the dairy waste—which is high in protein, vitamin A, and other bioactive substances—that is produced during the production of milk.



https://www.milestonesrl.com/es/blog2022/microwave-extraction/871-agro-food-waste-valorization-as-a-source-of-valuable-biochemicals-in-circular-economy-a-reality

i. **Restaurant derived**

Restaurant waste, also referred to as kitchen waste or leftover food, encompasses both raw and cooked food. The predominant component of restaurant waste is oil used for frying.

The Environmental Impact of Food Waste

The impact of food waste on the environment is significant and multifaceted. When food is wasted, not only are valuable resources such as water, energy, and land used in its production and transportation wasted, but also greenhouse gases are emitted during decomposition in landfills. Food waste contributes to climate change through the release of methane, a potent greenhouse gas, as organic matter breaks down anaerobically in landfill conditions. Moreover, the disposal of food waste in landfills leads to leachate production, which can contaminate soil and water sources, posing risks to human health and ecosystems. Additionally, the environmental footprint of food waste extends beyond its disposal phase, as it represents a loss of biodiversity and habitat destruction associated with agricultural production. Thus, addressing food waste is crucial not only for mitigating environmental degradation but also for promoting sustainability across the food system.

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A hidden treasure of bioactive compounds

Food waste holds immense potential as a hidden treasure trove of bioactive compounds. Despite being discarded, food waste contains valuable nutrients, antioxidants, and other bioactive substances that could be repurposed for various applications. By harnessing these compounds from food waste through innovative technologies and sustainable practices, we can not only reduce waste but also unlock new opportunities for the development of functional foods, dietary supplements, and other value-added products. Thus, viewing food waste as a reservoir of bioactive compounds offers a promising avenue for both environmental sustainability and nutritional innovation.

Unlocking the Value from Food Waste

Despite its negative impacts, food waste also presents opportunities for innovation and value creation. Several approaches can be employed to unlock the value from food waste:

1. Prevention and Reduction:

Prevention is the most effective strategy for addressing food waste. Businesses and consumers can adopt practices such as meal planning, proper storage, portion control, and food preservation techniques to minimize waste. Additionally, retailers can implement initiatives such as imperfect produce sales, surplus food redistribution, and dynamic pricing to reduce waste in the supply chain.

2. Recovery and Redistribution:

Food that is surplus but still edible can be recovered and redistributed to those in need through food banks, shelters, and charitable organizations. Food recovery programs can help alleviate hunger and reduce food waste simultaneously, creating a win-win situation for communities and the environment.

3. Recycling and Composting:

Organic waste, including food scraps and leftovers, can be recycled through composting or anaerobic digestion to produce nutrient-rich soil amendments or biogas for energy generation. Composting diverts organic waste from landfills, reduces methane emissions, and closes the nutrient loop in the food system.

4. Resource Recovery and Valorization:

Advanced technologies such as bioconversion, enzymatic hydrolysis, and pyrolysis can be used to extract value-added products from food waste, including biofuels, biochemicals, and bioplastics. These innovative approaches convert waste into valuable resources, creating economic opportunities and reducing environmental impact.

5. Public Awareness and Education:

Raising awareness about the issue of food waste and educating consumers about the consequences of wasteful behavior are essential steps in addressing the problem. Public campaigns, educational programs, and media initiatives can help shift societal norms and promote more sustainable consumption patterns.

Food waste valorization

Food waste valorization refers to the process of converting it into valuable products. This not only reduces the environmental impact of waste but also creates economic opportunities. Here are some types of products made from food waste through various valorization methods:

i. Biofuels

- **Biogas:** Produced through anaerobic digestion of food waste, biogas is a renewable source of energy that can be used for electricity, heating, or as a vehicle fuel.
- **Bioethanol**: Fermented from sugars and starches present in food waste, bioethanol is used as a fuel additive or alternative fuel for vehicles.
- **Biodiesel**: Derived from waste cooking oils and fats, biodiesel is a cleaner alternative to conventional diesel.

Animal Feed

- **Livestock Feed:** Food waste can be processed and converted into nutritious feed for livestock, reducing the need for conventional feed materials.

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- **Pet Food:** Certain food scraps can be repurposed into ingredients for pet food products.

Fertilizers and Soil Amendments

- **Compost:** Decomposed organic matter from food waste enriches soil fertility and improves soil structure.
- **Biochar:** Produced by pyrolysis of organic waste, biochar enhances soil health and sequesters carbon.
- **Biochemicals and Bio-based Materials**
- **Bioplastics:** Polymers derived from food waste components like starch, cellulose, or oils can be used to produce biodegradable plastics.
- **Platform Chemicals:** Chemicals like lactic acid, succinic acid, and citric acid, extracted from food waste, serve as building blocks for various industrial products.
- **Enzymes and Nutraceuticals:** Food waste can be a source of valuable enzymes and bioactive compounds for use in pharmaceuticals and health supplements.
- **Food Ingredients and Additives**
- **Flours and Powders:** Dehydrated and milled food waste, such as fruit and vegetable peels, can be turned into flours and powders for baking and cooking.
- **Pectin and Fibers:** Extracted from fruit and vegetable waste, these are used as gelling agents and dietary supplements.
- **Natural Colorants and Flavors:** Pigments and flavor compounds extracted from food waste can replace synthetic additives in food product.

Packaging Materials

- **Edible Packaging:** Made from food-grade materials derived from food waste, such packaging can reduce plastic waste.
- **Biodegradable Packaging:** Packaging materials produced from agricultural and food processing waste that decompose naturally.
- **Textiles and Other Products**
- **Fibers:** Some food waste, like banana peels and pineapple leaves, can be processed into fibers for textile production.
- **Cosmetics and Personal Care Products:** Extracts from food waste are used in formulations for skincare and haircare products due to their beneficial properties.

By implementing these valorization techniques, food waste can be transformed from an environmental burden into a resource that provides economic and ecological benefits.

Government policies regarding food waste managements

Save food share food

Provide programs, policies, and regulations that are strategically aligned with food loss and waste reduction objectives.

The Food Safety and Standards Authority of India (FSSAI) established the "Indian Food Sharing Alliance" (IFSA) in order to collaborate with other partner organizations, Food Recovery Agencies, and Non-Governmental Organizations (NGOs) in order to address India's food waste and hunger crisis.

RUCO- REPURPOSE USED COOKING OIL

The program, commonly referred to as "Repurpose Used Cooking Oil," or "RUCO," intends to convert animal fats, vegetable oils, and spent cooking oil from restaurants into biodiesel that can run diesel-powered vehicles and other diesel-powered machinery.

When oil is used repeatedly for frying, it changes its characteristics and forms Total Polar Compounds (TPC). These substances are harmful and have been connected to a number of illnesses, including as liver problems, atherosclerosis, hypertension, and Alzheimer's disease. Thus, it is essential to keep an eye on the quality of vegetable oils when frying in order to safeguard consumer health. In order to do this, vegetable oil cannot be utilized if Total Polar

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Compounds exceed the FSSAI's set limit of 25%. In order to comply with these laws, all Food Business Operators (FBOs) must monitor the oil quality while frying as of July 1, 2018.

In order to end present illegal activities and remove used cooking oil from the food value chain, the FSSAI is putting its EEE Strategy into action. This plan encourages environmentally sustainable development, improves energy security, curbs global warming, and advances the health and wellbeing of all 130 crore people.

Education Enforcement Ecosystem

Safe and Sustainable Packaging in Food and Beverage Sector

The Food and Sanitation Authority of India (FSSAI) is leading programs like Jaivik Bharat, which promotes authentic organic food; Save Food, Share Food, which reduces food waste and encourages food donation; Safe and Sustainable Packaging in the Food and Beverage Sector, which lowers the use of plastics; and Repurpose Used Cooking Oil (RUCO), which promotes the safe and healthy use of cooking oil and the recycling of used cooking oil into soap, biodiesel, and other useful products.

In order to guarantee that every person consumes safe, healthful food in a sustainable manner, Eat Right India seeks to expand all of these programs at the national level.

Conclusion:

Food waste is a complex and multifaceted issue with far-reaching consequences for society, the economy, and the environment. However, it also presents opportunities for innovation, collaboration, and positive change. By adopting a holistic approach that encompasses prevention, recovery, recycling, and resource recovery, we can unlock the value from food waste and create a more sustainable and resilient food system. Together, we can turn waste into opportunity and build a future where food is valued, not wasted.

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Can Plants Get Cancer? Understanding Galls and Tumors in Plants

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When we hear the word "cancer," we often think of uncontrolled cell growth in humans and animals. But have you ever wondered, can plants get cancer too? The answer is both fascinating and complex. While plants don't get cancer in the same way humans do, they do develop tumor-like growths, often referred to as galls, due to a variety of causes including pathogens, insects, and even genetic mutations.

What Is Cancer, and How Is It Different in Plants?

In animals, cancer is caused by unregulated cell division, often triggered by genetic mutations, leading to the formation of malignant tumors that can invade other tissues (metastasis). Plants also experience unregulated growth, but there are two key differences:

- Plant cells are locked in place by rigid cell walls, so they can't migrate the way animal cancer cells can. This makes true metastasis in plants virtually impossible.
- Plants have more modular and regenerative growth. Damage to one part doesn't necessarily affect the whole organism.

What Are Galls?

Galls are abnormal outgrowths of plant tissues, much like benign tumors. They are often induced by: Insects (e.g., gall wasps, aphids, midges), Fungi (e.g., *Exobasidium* spp.), Bacteria (e.g., *Agrobacterium tumefaciens*), Nematodes and Viruses. Galls can form on leaves, stems, flowers, roots, or even fruits, and they are usually localized and non-lethal to the plant.

Mechanism of Crown Gall Formation by bacteria (*Agrobacterium tumefaciens*)

The gall formation by *Agrobacterium tumefaciens* involves a natural process of horizontal gene transfer. Here's how it works step-by-step:

1. **Wound Entry:** The bacterium enters the plant through wounds caused by pruning, insect bites, grafting, or mechanical injury. It is

chemotactically attracted to phenolic compounds and sugars released from wounded plant tissues.

2. **Attachment to Plant Cells:** The bacterium attaches to the surface of plant cells at the wound site. Attachment is mediated by bacterial surface polysaccharides and proteins.
3. **Activation of Virulence (*vir*) Genes:** Plant-released phenolic compounds (especially acetosyringone) activate the *vir* genes located on the Ti (tumor-inducing) plasmid within the bacterium.
4. **T-DNA Processing and Transfer:** A segment of the Ti plasmid known as T-DNA (Transfer DNA) is excised by *VirD1/VirD2* endonuclease complex. The T-DNA is transferred into the plant cell in a single-stranded form, coated by VirE2 proteins for protection.
5. **T-DNA Integration into Plant Genome:** The T-DNA enters the nucleus of the plant cell and integrates randomly into the plant genome. This integration causes the plant to express foreign genes carried on the T-DNA.
6. **Tumor and Opine Production:** The T-DNA region of *Agrobacterium tumefaciens* contains genes that induce the overproduction of plant hormones such as auxins (indole-3-acetic acid, IAA) and cytokinins, resulting in uncontrolled cell division and the formation of tumors or galls in infected plant tissues. Additionally, the T-DNA encodes enzymes responsible for the synthesis of opines—unusual amino acid derivatives like octopine and nopaline—which serve as a unique nutrient source exclusively utilized by the bacterium.

Mechanism of Gall Formation by Fungi in Plants

1. **Pathogen Entry and Infection Initiation**: Gall formation by fungi in plants begins with the entry of fungal spores or hyphae into host tissues. This can occur through natural openings such as stomata and lenticels, through wounds, or via direct penetration of the plant surface. The latter is facilitated by specialized infection structures like appressoria or by the enzymatic degradation of the cuticle and cell wall. Once inside, the fungus establishes itself by forming a biotrophic or hemibiotrophic relationship with the host, allowing it to colonize plant tissues without immediately killing them.
2. **Induction of Gall Formation**: After successful colonization, the fungus manipulates host cellular processes to initiate gall formation. One of the primary mechanisms involves hormonal manipulation, particularly of auxins and cytokinins. Elevated levels of auxins promote abnormal cell elongation, while increased cytokinins stimulate excessive cell division. This hormonal imbalance leads to hyperplasia (increased cell number) and hypertrophy (increased cell size), both of which contribute to the abnormal tissue swelling characteristic of galls.
3. **Role of Effectors and Gall Development:** In addition to hormonal disruption, fungi secrete a suite of effector proteins and enzymes that suppress the host's immune responses and reprogram gene expression related to development and defense. These effectors may also alter vascular tissues to redirect the flow of nutrients toward the infection site, further supporting gall development. As a result, the infected region swells significantly, with fungal hyphae colonizing the gall tissue—either remaining intercellular or forming specialized feeding structures such as haustoria.
4. **Maturation and Sporulation:** As the gall matures, it becomes a nutrient-rich sink that supports sustained fungal growth while impairing the normal function of the plant. Eventually, the fungus produces reproductive structures—fruiting bodies—within or on the gall surface. These structures facilitate sporulation, and the newly formed spores are released into the environment, enabling the pathogen to spread and initiate new infections in other susceptible plants.

Several fungal and fungus-like pathogens are known to induce gall formation in different host plants. *Ustilago maydis*, the causative agent of corn smut, induces prominent galls on various parts of the maize plant, including ears, tassels, and stalks. In coriander, stem galls are formed due to infection by *Protomyces macrosporus*, which causes noticeable swelling and distortion of the stems. Clubroot disease in cruciferous crops is caused by *Plasmodiophora brassicae*, a soil-borne, fungus-like organism (plasmodiophorid), which leads to the formation of large, club-shaped root galls that disrupt water and nutrient uptake. Additionally, crown gall symptoms in chrysanthemum have been reported to be associated with *Olpidium brassicae*, further illustrating the diversity of gall-inducing fungal pathogens across plant species.

Mechanism of Gall Formation by nematodes in Plants

Plant-parasitic nematodes, especially **root-knot nematodes** (*Meloidogyne* spp.), induce gall formation on plant roots through highly specialized interactions. These nematodes are sedentary endoparasites that manipulate plant cells to form specialized feeding structures. Mechanism of gall formation by nematodes as fallows

1. **Penetration and Migration:** The infection process begins when second-stage juvenile (J2) nematodes hatch from eggs in the soil and locate the host plant roots. They typically penetrate the root tissue just behind the root cap and migrate intercellularly through the cortex until they reach the vascular cylinder, usually near the xylem. This targeted movement is crucial for establishing a successful feeding site.
2. **Initiation of Feeding Site**: Upon reaching the appropriate region within the root, the nematode selects a few cells in the pericycle or endodermis and initiates the formation of a specialized feeding site. Using its stylet, the nematode injects secretions from its esophageal glands into the host cells. These secretions contain various effector proteins and enzymes that manipulate the host's cellular machinery and gene expression to favor nematode development.
3. **Giant Cell Formation and Gall Development**: As a result of the nematode's secretions, the selected host cells undergo repeated nuclear division without cell division (a process known as endomitosis), leading to the formation of large, multinucleate giant cells. Surrounding cells also enlarge due to hyperplasia and hypertrophy, collectively forming a visible swelling or gall, commonly referred to as a root-knot.
4. **Nutrient Sink and Plant Symptoms**: The gall serves as a nutrient sink, redirecting the plant's resources toward the nematode feeding site. The nematodes remain sedentary, feeding on the giant cells for the remainder of their development. Over time, infected plants exhibit characteristic symptoms such as swollen, knotted roots, stunted growth, chlorosis, and significant yield reduction, especially under high infestation pressure.

Mechanism of Gall Formation by Viruses

While viruses typically cause systemic symptoms (mosaic, chlorosis, stunting), some viruses lead to tumor- or gall-like structures in plants. These symptoms often result from virus-induced hormonal imbalance and abnormal cell proliferation**.**

1. **Virus Entry and Movement:** Plant viruses gain entry into host cells primarily through vector transmission—most commonly by aphids, nematodes, or other insects—although mechanical injury and grafting can also introduce viral particles. Once inside a cell, the virus hijacks the host machinery to replicate its genome and synthesize coat and movement proteins. These movement proteins enable the virus to traverse cell walls via plasmodesmata, establishing localized infection foci, and ultimately to spread systemically through the phloem.
2. **Disruption of Gene Expression:** Following entry, viral proteins interfere with the plant's developmental and defense pathways. Many viruses carry suppressors of RNA silencing that neutralize the host's primary antiviral mechanism,

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leading to broader dysregulation of gene expression. By targeting key regulatory genes involved in cell cycle control and hormone biosynthesis or signaling, these viral factors set the stage for abnormal cell proliferation.

3. **Hormonal Imbalance and Gall Induction:** A hallmark of virus-induced galls is the perturbation of plant hormone homeostasis. Viral infection often elevates or mislocalizes levels of auxins, cytokinins, and other growth regulators. These hormonal changes provoke hyperplasia (an increase in cell number) and hypertrophy (an increase in cell size) at sites of infection, producing tumor- or gall-like swellings that deviate markedly from healthy tissue morphology.

Several well-documented plant diseases exemplify this phenomenon. Peach wart disease virus induces rough, wart-like galls on both fruit and foliage. Tobacco leaf curl virus triggers pronounced leaf curling and outgrowths resembling tumors. Petunia flower break virus causes dramatic distortion of floral tissues, leading to tumorous proliferations. In each case, the combination of viral movement, gene-silencing suppression, and hormone misregulation culminates in gall formation rather than the more common systemic symptoms.

Mechanism of Gall Formation by Insects:

1. **Insect Ovulation**: The insect (usually an adult) lays its eggs on or inside the plant tissue, typically on leaves, stems, roots, or flowers. These eggs are often placed in a specific area of the plant, often where tissues are tender or more easily manipulated.
2. **Salivary Secretions and Plant Response**: Upon hatching, the larvae start feeding on plant tissues. During feeding, insects, especially *gall-forming* species like aphids, mites, or wasps, release chemical substances through their saliva. These chemicals can include growth regulators, such as plant hormones (auxins, cytokinins, or jasmonic acid), which alter the normal plant cell division and differentiation.
3. **Cellular Proliferation and Gall Formation**: The plant's natural response to the chemicals from the insect leads to rapid cell division and changes in cell growth. This causes the surrounding plant tissue to swell and form a gall. The gall tissue is usually much denser and more compartmentalized than normal plant tissue.
4. **Gall Structure**: The structure of the gall provides a safe and nutrient-rich environment for the developing larvae. Galls can take various shapes, such as spherical, elongated, or convoluted, depending on the insect species and its feeding site.
5. **Larval Development**: The larvae feed inside the gall, where they are protected from predators and environmental stresses. The gall structure can sometimes even secrete nutrients that nourish the insect larvae, enabling them to grow and mature inside the gall.
6. **Exit and Gall Closure**: Once the larvae have matured, they exit the gall, often through exit holes they create. In some cases, the gall might continue to grow after the larvae leave, but it eventually dries up and decays.

For example, gall midges (*Cecidomyiidae*, Diptera) induce distinctive galls on leaves and flower buds in a variety of host plants. Aphids and psyllids (Hemiptera) also form leaf curls and pouch-like galls by injecting salivary secretions that alter plant cell growth. Gall wasps (Cynipidae, Hymenoptera) are notorious for forming complex, often woody galls on oak trees. Thrips (Thysanoptera) induce galls in flowers and leaves, particularly in crops like chili and cotton.

Conclusion

Galls and tumors in plants are abnormal growths caused by a range of organisms such as fungi, bacteria, viruses, nematodes, and insects. These agents disrupt normal plant development by altering hormone levels or gene expression, leading to excessive cell division and tissue swelling. While these structures often serve as protective and nutrient-rich sites for the invading organisms, they can reduce plant vigor, affect yield, and make plants more susceptible to secondary infections. Despite their harmful effects, galls and tumors can also offer valuable insights into plant developmental biology and host-pathogen interactions. Effective management involves integrated approaches such as resistant varieties, proper sanitation, timely pest and disease control, and minimizing stress conditions that favor infection. Understanding the causes and mechanisms of gall formation is essential for protecting crops and maintaining healthy plant systems.

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Managing Heat Stress in Summer Fruit Orchards: A Challenge for the Deccan Plateau regions

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Summer heat stress has emerged as a major challenge for fruit orchard productivity in India's Deccan Plateau, particularly during the critical months of March to May. Many economically important fruits—such as mango, pomegranate, guava, and sapota—that flower and bear fruit during this season face substantial stress as daytime temperatures often exceed 42–46°C, surpassing the cardinal maximum thresholds of these crops. Recent reports indicate that average summer temperatures in the Deccan Plateau have increased by 1.2–1.5°C over the last three decades, with peaks reaching 46°C in May 2024. Such high-intensity heat stress results in significant physiological disruptions, flower and fruit drop, sunburn, poor fruit quality, and shortened shelf life. The resulting economic loss is substantial, with heat stress reportedly causing 20–40% yield losses, translating to an estimated loss of ₹5,000–6,000 crores annually in India's fruit sector. To sustain fruit production under rising temperatures, orchardists must adopt integrated strategies including canopy management (pruning and training), protective measures (shade nets, mulching, windbreaks), physiological support (foliar nutrient sprays, anti-transpirants), and selective harvesting practices. Long-term approaches such as climate-smart orchard design, use of heat-resilient fruit varieties, and improved soil-water management are critical to coping with heat stress and achieving high productivity of summer-fruiting crops.

A comprehensive study analyzing temperature trends over India from 1931 to 2002 found significant increases in both maximum and minimum temperatures over the Deccan Plateau. While the diurnal temperature range remained relatively stable, the consistent rise in maximum temperatures has become a cause for concern, particularly for agriculture and horticulture in the region (**Reddy** et al.,2017). Further research, focusing on the period from 1986 to 2015, reveals that the pre-monsoon season (March–May) has witnessed the highest warming trend in India. Specifically, maximum temperatures during this season have increased at a rate of 0.29°C per decade. This accelerated warming during the critical growth period for many crops underscores the vulnerability of the agricultural sector to climate change.

In recent years, the Deccan Plateau region, which includes areas such as Maharashtra, Telangana, and Karnataka, has experienced a significant increase in maximum temperatures during the summer months of April and May. Reports from the India Meteorological Department (IMD) confirm that temperatures during these months have regularly surpassed historical averages, often reaching between 45°C and 46°C in the peak summer months. For instance, in April 2022, temperatures in parts of the Deccan Plateau crossed 45°C, and in May 2024, some regions recorded extreme highs of 46.2°C (IMD, 2024). These elevated temperatures exceed the maximum tolerable limits of many summer fruit trees. Most common fruit trees, including mango, pomegranate, and guava, have an upper temperature tolerance range of 38°C to 42°C. When temperatures exceed these limits, these trees face significant physiological stress, resulting in a range of adverse outcomes.

The consistently high temperatures in the Deccan Plateau region, regularly surpassing 42°C, significantly impact fruit trees, particularly those sensitive to heat stress, such as mangoes, pomegranates, and guavas. When temperatures exceed 42°C, flower and fruit drop occur, reducing yield potential. Excessive heat disrupts pollen viability and fertilization, preventing successful fruit set and leading to early fruit and flower drop (Bhise, 2022). Furthermore, temperatures above this threshold can cause fruit sunburn, particularly in varieties like pomegranates and guavas, resulting in blemishes, cracks, or even internal damage to the fruit, which degrades quality and marketability (Lal and Sahu, 2017). High temperatures also exacerbate water stress; despite regular irrigation, excessive heat causes rapid evaporation from the soil and leaves, limiting the amount of water available for trees. This further hinders tree growth as they struggle to meet their water demand for cooling and nutrient uptake (IMD, 2024). In May 2024, temperatures peaked at 46°C, well beyond the 42°C upper limit for many summer fruit trees. This temperature surge, which has been observed to be 2–6°C above the usual tolerance range, poses a significant threat to the growth and yield of these fruit crops, underscoring the challenges posed by rising summer heat.

The economic consequences of higher summer temperatures on fruit orchards are profound and multifaceted. Reduced yields, compromised fruit quality, increased post-harvest losses, higher irrigation costs, and the need for additional pest and disease management all contribute to declining orchard profitability. The cumulative economic loss from heat stress across various fruit crops in India, including mangoes, pomegranates, guavas, citrus, grapes, and apples, could amount to ₹5,000-6,000 crores (approximately $670 million to $800 million) annually. This represents a significant portion of India's horticultural income, with heat stress emerging as a major challenge for fruit productivity and quality (Datta, 2013; Nisar et al., 2015). As climate change continues to drive fluctuations in temperature and weather patterns, these challenges will likely intensify, making it imperative for orchardists to adopt adaptive strategies to maintain the financial sustainability of their operations. Such strategies may include better temperature management, improved irrigation techniques, and the use of heat-tolerant fruit varieties.

Cardinal Temperature refers to the range of temperatures that determine plant growth and development. The minimum and optimum temperatures are essential for healthy growth, while the maximum temperature is the upper limit above which the plant experiences stress. Heat Intensity Over Maximum Temperature indicates how much the temperature exceeds the maximum tolerable limit for each fruit tree. For example, if temperatures rise by 4-6°C above the maximum threshold, the tree experiences significant physiological stress.

Table 1. Cardinal temperature of fruit trees and Summar heat intensity of the Deccan plateau region

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Fruit	Cardinal Temperature (°C)	Maximum Tolerable Temperature (°C)	Heat Intensity Over Maximum Temperature (°C)	Reference for Cardinal Temperature
Mango	Min: 15°C, Optimum: 27-30°C, Max: 40-42°C	40-42°C	2-6°C above max tolerance	Bhattacharyya et al., 2021
Pomegranate	Min: 10°C, Optimum: 25-30°C, Max: 38-42°C	38-42°C	4-8°C above max tolerance	Adiba et al. (2024)
Guava	Min: 10°C, Optimum: 25-30°C, Max: 38-42°C	38-42°C	4-6°C above max tolerance	Singh et al., 2017
Citrus	Min: 15°C, Optimum: 25-30°C, Max: 38-40°C	38-40°C	4-6°C above max tolerance	Nisar et al., 2015
Grapes	Min: 10°C, Optimum: 22-30°C, Max: 40-42°C	40-42°C	4-6°C above max tolerance	Dhillon et al., 2019
Papaya	Min: 20°C, Optimum: 25-30°C, Max: 35-38°C	35-38°C	4-7°C above max tolerance	Ghosh et al., 2017 (Indian Horticulture)
Banana	Min: 15°C, Optimum: 25-30°C, Max: 38-40°C	38-40°C	4-6°C above max tolerance	Turner et al., (1983)

Heat Stress Impact on Growth and Development of Summer Fruit Orchards

Heat stress during summer months significantly affects the growth and productivity of fruit orchards in the Deccan Plateau. When temperatures rise above the critical thresholds (typically around 42°C), several physiological and metabolic processes in fruit trees are disrupted, leading to reduced growth, impaired fruit development, and lower yields.

One of the earliest impacts of high temperatures is the decline in photosynthesis. Enzymes involved in the process become less efficient above 42°C, reducing energy availability for growth and fruit development. As a result, trees often exhibit stunted growth, smaller leaves, and overall reduced vigor. In extreme heat, some trees may even enter temporary dormancy as a survival response (Sharma et al., 2020).

High temperatures also affect flowering and fruit set. Critical crops like mango and pomegranate experience flower drop and poor pollination when exposed to temperatures exceeding 42°C, due to reduced pollen viability and disrupted fertilization (Chawla et al., 2011). This leads to a significant decrease in fruit set and eventual yield.

Furthermore, fruit development suffers under intense heat. Fruits such as pomegranate and guava are particularly prone to sunburn when exposed to temperatures beyond their tolerance limits, causing blemishes, cracks, and internal damage, thus lowering their marketability (Galindo et al., 2017). In addition, elevated temperatures increase soil and leaf water evaporation, causing water stress despite regular irrigation (Chaikiattiyos et al., 1994).

Overall, sustained heat stress creates a cascading negative effect—compromising growth, fruit set, and fruit quality. With climate change driving further temperature increases, adaptive measures like the use of shade nets, improved irrigation practices, and the adoption of heat-tolerant varieties will be crucial for sustaining orchard productivity.

Impact of high temperature on post-harvest changes of Summar fruits

High summer temperatures significantly impact the post-harvest quality and shelf life of fruits such as mangoes, guavas, grapes, and pomegranates. Exposure to extreme heat, either during or after harvest, triggers a series of physiological and biochemical changes that accelerate spoilage, reduce market value, and lower consumer appeal (Elyatem and Kader, 1984).

Accelerated Ripening

Excessive heat accelerates fruit ripening by increasing the breakdown of starches into sugars and stimulating ethylene production. This leads to over-ripening, uneven ripening, and spoilage in fruits like mango and pomegranate, shortening their shelf life (Sharma et al., 2023).

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Increased Respiration

Higher temperatures raise the respiration rate of fruits, depleting their internal energy reserves more quickly. This speeds up senescence and results in softening and flavor loss, especially in apples and pomegranates (Hasbullah et al., 2001).

Water Loss and Shrinkage

High heat, particularly when combined with low humidity, causes rapid moisture loss, resulting in fruit shrinkage, wrinkling, and reduced consumer appeal. Fruits harvested under heat stress are more susceptible to dehydration and post-harvest quality loss (Chen et al., 2021.

Sunburn and Skin Damage

Fruits exposed to direct sunlight above 42°C often suffer from sunburn, cracks, and internal damage. These blemishes affect the fruit's visual quality and can lead to increased microbial vulnerability (Doke et al., 2024).

Microbial Spoilage

Heat stress creates favourable conditions for microbial growth. Warm, humid conditions increase the risk of fungal and bacterial spoilage in highly perishable fruits like mango and guava (Sahu and Shrivas, 2024).

Nutrient Loss

Heat-sensitive nutrients like vitamin C and certain antioxidants degrade quickly under high temperatures, reducing the nutritional quality of fruits (Stewart and Ahmed, 2020).

Management Strategies

When irrigation alone cannot mitigate heat stress, orchardists should adopt integrated strategies such as shade nets, mulching, anti-transpirants, and selecting heat-tolerant varieties. These measures can reduce fruit loss, preserve quality, and maintain productivity during peak summer months.

1. Use of Shade Nets

Shade nets are highly effective in protecting orchards from excessive heat by lowering canopy temperatures by 5–7°C during peak periods. They reduce direct sunlight exposure, helping prevent sunburn, fruit drop, and excessive soil evaporation, thereby maintaining fruit quality, particularly in heat-sensitive fruits like mangoes, pomegranates, and guavas (Mditshwa et al., 2019).

Heat intensity of the Summar Season

- Daily Mean Temperature Range: 35°C to 45°C in tropical regions during peak summer.
- Tropical fruit threshold: Optimal max temp for most tropical fruits is ~30–35°C.
- Stress Range: Summer temperatures exceed optimal limits by 5–10°C, triggering heat stress

Impact on Growth and Development

- Delayed or stunted vegetative growth.
- Reduced flower initiation and fruit set.
- Shortened fruit development period.
- Increased fruit drop due to poor pollen viability

Physiological Impacts

- Increased transpiration rate and leaf temperature.
- Stomatal closure → reduced CO_2 uptake.
- Photosynthetic inhibition due to enzyme deactivation.
- Oxidative stress from excess ROS (Reactive Oxygen Species).

- **Nutrient Content**
- Decreased **nutrient uptake** (Ca, Mg, N, K).
- Reduced **translocation** to fruits.
- Micronutrient deficiencies (Zn, Fe) become more apparent.
- Imbalance in **cation: anion ratios** affects fruit development.

- **Biochemical Changes**
- Elevated antioxidant enzyme activity (CAT, POD, SOD) as stress response.
- Increased proline and soluble sugars as Osmo protectants.
- Reduced chlorophyll and protein content.
- Altered secondary metabolite production (phenols, flavonoids).

- **Fruit Quality and Yield**
- **Sunburn, cracking, and poor fruit size.**
- Altered **sugar-acid balance** affecting taste.
- **Skin browning, color changes, and poor shelf life.**
- Overall **yield reduction** by 15–50% depending on fruit type and heat severity.

Fig 1. Overview of heat stress impact on fruit trees

2. Mulching

Applying organic mulch (e.g., straw, wood chips) around the tree base helps conserve soil moisture, lower soil temperatures, and suppress weeds. Mulching not only mitigates heat stress on roots but also improves soil health and supports sustained fruit production during high-heat periods (Singh and Jat, R., 2024).

3. Pruning for Improved Canopy Airflow

Strategic pruning reduces canopy density, enhancing air circulation and light penetration. This helps lower canopy temperatures, reduces sunburn risk, and improves fruit quality. Careful removal of non-

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productive or diseased branches also minimizes water stress and boosts nutrient uptake (Ashraf and Ashraf, 2014).

4. Use of Anti-Transpirants

Anti-transpirants form a protective film on leaves, reducing water loss through transpiration. Their use during heat waves helps trees conserve moisture, maintain photosynthesis, and reduce flower and fruit drop, ultimately supporting fruit quality under water-limited conditions (ElSadek et al., 2024).

5. Foliar Nutrient Feeding

High temperatures often cause nutrient deficiencies, particularly of potassium, calcium, and nitrogen. Foliar sprays provide quick nutrient uptake, improving heat tolerance, fruit set, and quality. Potassium enhances water-use efficiency, while calcium prevents disorders like blossom-end rot (Piñero et al., 2021).

6. Establishing Windbreaks

Windbreaks, such as rows of trees or shrubs, protect orchards from hot, drying winds that intensify water loss. By reducing wind speed, they lower transpiration rates, conserve soil moisture, and create a favourable microclimate for better fruit set and retention (Chawla et al., 2011).

7. Selective Harvesting

Under heat stress, selectively harvesting fruits before excessive ripening or sunburn sets in helps preserve quality and minimize economic loss. Early harvesting of sensitive fruits while allowing heat-tolerant varieties to mature naturally can sustain marketable yields.

Conclusion

When irrigation alone is insufficient to mitigate heat stress, integrating strategies like shade nets, mulching, pruning, anti-transpirants, foliar feeding, windbreaks, and selective harvesting becomes crucial. These measures not only safeguard fruit quality and yield but also enhance the resilience of orchards against increasing climate variability.

References

Adiba, A., Radouane, N., Boudad, H., Outghouliast, H., Haddioui, A., Hamdani, A., & Charafi, J. (2024). Impact of thermal conditions on pomegranate (Punica granatum L.) biochemical traits: a comparative study of genotypic responses under contrasting climates. *Vegetos*, 1-13.

Bhattacharyya, T., Haldankar, P., Haldavanekar, P., Burondkar, M., Salvi, B., & Chakurkar, E. (2021). Impact of climate change on horticulture in Konkan, Maharashtra: activities and strategies. *Indian J. Fertil*, *17*, 258-273.

Singh, S. K., Malhotra, S. K., Bhargava, R., Singh, R. S., & Shukla, A. K. (2017). Morphological and physiological characterization of guava (Psidium guajava) under hot-arid zone of Rajasthan. *Indian Journal of Agricultural Sciences*, *87*(4), 491.

Nisar, M., et al. (2015). Temperature stress and heat tolerance in citrus crops. Hindustan Times.

Dhillon, W. S., & Gill, P. P. S. (2011). *Climate change and fruit production*. PAU.

Ghosh, S. K., et al. (2017). *Papaya tolerance to temperature extremes and growth conditions. Indian Horticulture*.

Turner, D. W., & Lahav, E. (1983). The growth of banana plants in relation to temperature. *Functional Plant Biology*, *10*(1), 43-53.

Reddy, A. G. K., Kumar, J. S., Maruthi, V., Venkatasubbaiah, K., & Rao, C. S. (2017). Fruit production under climate changing scenario in India: a review. Environment & Ecology, 35(2B), 1010-1017.

Bhise, D. R. (2022). *Effect of heat units in different varieties of mango (Mangifera Indica L)* (Doctoral dissertation, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani).

Lal, N., & Sahu, N. (2017). Management strategies of sun burn in fruit crops-A Review. International Journal of Current Microbiology and Applied Sciences, 6(6), 1126-1138.

Datta, S. (2013). Impact of climate change in Indian horticulture-a review. International Journal of

ISSN: 3049-2289

Science, Environment and Technology, 2(4), 661-671.

Sharma, S. (2020). Heat stress effects in fruit crops: A review. Agricultural Reviews, 41(1), 73-78.

Chawla, R., Sheokand, A., Rai, M. R., & Kumar, R. (2011). Impact of climate change on fruit production and various approaches to mitigate these impacts. Tropical Fruits, 10(3), 564-571.

Chaikiattiyos, S., Menzel, C. M., & Rasmussen, T. S. (1994). Floral induction in tropical fruit trees: effects of temperature and water supply. *Journal of Horticultural Science*, *69*(3), 397-415.

Galindo, A., Calín-Sánchez, Á., Griñán, I., Rodríguez, P., Cruz, Z. N., Girón, I. F., ... & Hernández, F. (2017). Water stress at the end of the pomegranate fruit ripening stage produces earlier harvest and improves fruit quality. *Scientia Horticulturae*, *226*, 68-74.

Elyatem, S. M., & Kader, A. A. (1984). Post-harvest physiology and storage behaviour of pomegranate fruits. *Scientia Horticulturae*, *24*(3-4), 287-298.

Sharma, M., Negi, S., Kumar, P., Srivastava, D. K., Choudhary, M. K., & Irfan, M. (2023). Fruit ripening under heat stress: The intriguing role of ethylene-mediated signaling. Plant Science, 335, 111820.

Hasbullah, R., KAWASAKI, S., KOJIMA, T., & AKINAGA, T. (2001). Effect of heat treatments on respiration and quality of 'Irwin'mango. Journal of the Society of Agricultural Structures, Japan, 32(2), 59-67.

Chen, K., Sun, J., Li, Z., Zhang, J., Li, Z., Chen, L., ... & Zhang, K. (2021). Postharvest dehydration temperature modulates the transcriptomic programme and flavonoid profile of grape berries. *Foods*, *10*(3), 687.

Doke, A., Kakade, V. D., Patil, R. A., Morade, A. S., Chavan, S. B., Salunkhe, V. N., ... & Reddy, K. S. (2024). Enhancing plant growth and yield in dragon fruit (Hylocereus undatus) through strategic pruning: A comprehensive approach for sunburn and disease management. *Scientia Horticulturae*, *337*, 113562.

Sahu, M., & Shrivas, A. (2024). Exploring Microbial Spoilage in Fruits: Causes, Detection Methods, and Preventive Measures. International Journal of Innovative Research in Technology and Science, 12(2), 470-477.

Stewart, A. L., & Ahmed, S. (2020). Effects of climate change on fruit nutrition. Fruit crops, 77-93.

Mditshwa, A., Magwaza, L. S., & Tesfay, S. Z. (2019). Shade netting on subtropical fruit: Effect on environmental conditions, tree physiology and fruit quality. Scientia Horticulturae, 256, 108556.

Singh, V. P., & Jat, R. (2024). Combating abiotic stresses in fruit crops through mulching. th4 Global Meet on Science and Technology, 139.

Ashraf, N., & Ashraf, M. (2014). Summer pruning in fruit trees. *African Journal of Agricultural Research*, *9*(2), 206-210.

ElSadek, M. A., Abdel Rahman, A. A. S., & Saeed, H. (2024). Effect of foliar spraying with some anti-transpirants on yield and quality of fruits of. *Aswan University Journal of Sciences and Technology*, *4*(4), 152-161.

Piñero, M. C., Otálora, G., Collado, J., López-Marín, J., & Del Amor, F. M. (2021). Foliar application of putrescine before a short-term heat stress improves the quality of melon fruits (Cucumis melo L.). Journal of the Science of Food and Agriculture, 101(4), 1428-1435.

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Agri-Fintech Revolutionizing Farming

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Agri-Fintech is the integration of agricultural practices with financial technology to improve farmers' credit access, insurance, and electronic payments. It enables smallholders through mobile banking, artificial intelligence-based credit scoring, and data-informed decision-making. Through the mitigation of conventional issues such as financial exclusion and market risks, Agri-Fintech fosters efficiency, resilience, and sustainability in agriculture. Its coupling with next-generation technologies and favorable policies is facilitating a digital revolution in farming, which guarantees inclusive growth and food security.

Agri-Fintech is a new discipline that brings agriculture together with financial technology or Fintech to develop cutting-edge solutions for farmers, especially smallholders and rural producers. Agri-Fintech aims to enhance access to finance, support better decision-making, and increase productivity along the value chain in the agricultural sector. Rayhan *et.al.* 2024.

In a nutshell, Agri-Fintech makes it easier for farmers to access financial services through the application of new technologies such as mobile applications, online platforms, and machine learning. This integration assists in closing the gap between rural farmers and formal finance.

Some of the most effective tools and services that come under Agri-Fintech are:

- Digital payment systems to purchase seeds, fertilizers, and other inputs,
- Crop insurance schemes that can be accessed and settled online,
- Mobile banking services that address the rural population's needs,
- Farm data analytics to inform investment and credit decisions, and

- AI/ML-driven credit scoring mechanisms that enable lenders to evaluate a farmer's creditworthiness based on farm data, mobile usage, and satellite imagery.

3.Why is Agri-Fintech Needed?

Agriculture, particularly in developing nations, is challenged by three things—financial exclusion, high risk, and limited infrastructure. Recent research indicates that more than 70% of smallholder farmers in rural areas are unbanked or underbanked. This hinders them from accessing credit when needed, mitigating risks, or investing in new technologies. Prajapati *et.al.* 2023.

Conventional banking mechanisms are not always designed to cater to farmers' needs. Loan procedures are tedious, paper-heavy, and collateral-dependent, which are things that most smallholders cannot offer. Also, the risk-prone nature of agriculture—owing to unexpected climatic conditions, pest attacks, and market price volatility—introduces an element of uncertainty that discourages typical lenders.

In this regard, Agri-Fintech is a revolutionary solution. Through real-time data, automation, and digital platforms, it allows financial institutions to better evaluate agricultural risks and extend services such as microloans, savings accounts, insurance, and subsidies directly to farmers.

Agri-Fintech is more than a financial product—it is a rural empowerment revolution, a foundation for sustainable agriculture, better livelihoods, and inclusive growth.

4. Key Elements of Agri-Fintech

The Agri-Fintech system is based on a number of innovative building blocks that are revolutionizing farmers' access, handling, and derivation of financial services. These building blocks are made to be available, data-based, and inclusive, enabling farmers to make better choices and handle farming risks more successfully. Some of the main pillars of Agri-Fintech are given below:

1. Digital Payments

Digital payments represent a major breakthrough in Agri-Fintech, enabling farmers to use platforms like UPI, e-wallets, and QR codes to buy inputs, pay labor, and receive payments seamlessly. This shift from cash to digital transactions makes payments faster, more secure, and fully traceable. It significantly reduces reliance on physical cash, minimizing risks of theft or loss. Digital payments also enhance financial transparency, cutting down corruption and delays, especially in subsidy disbursement. The Direct Benefit Transfer (DBT) system leverages digital payments to deliver government subsidies directly into farmers' accounts, ensuring timely and corruption-free support. Glavanits *et.al.* 2024

2. Microcredit and Agri-Loans

Access to credit is a major hurdle for smallholder farmers lacking collateral or formal credit histories. Agri-Fintech platforms are transforming this by offering microcredit and agri-loans through easy digital channels. These services leverage AI-powered credit scoring, which uses alternative data like mobile activity, farming patterns, weather, and satellite imagery to assess creditworthiness. Loan applications and e-KYC verification are completed entirely via mobile devices, streamlining the process. Flexible repayment options such as "Pay-as-you-harvest" align loan repayment with farmers' income cycles, easing financial pressure and improving loan affordability and accessibility.

3. Precision Financing

Precision financing tailors farm credit based on specific farm conditions such as crop type, soil health, climate, and market access. Using real-time data and analytics, it provides customized loan amounts and repayment schedules aligned with productivity and seasonal cycles. This approach includes risk-sharing models where insurers partner with banks to mitigate losses from weather or pests. Integration with farm management software and IoT devices allows continuous monitoring to optimize credit use. By preventing both underfinancing and overfinancing, precision financing improves farm productivity, reduces loan defaults, and strengthens

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farmers' financial resilience against agricultural risks.

4. Emerging Technologies in Agri-Fintech

Agri-Fintech is being driven by a set of cutting-edge technologies that are transforming the way financial services are provided in the agriculture industry. Not only do these technologies enhance the efficiency and precision of financial choices but also introduce customized solutions to farmers through the use of real-time data. The combination of these tools is making an intelligent, responsive, and adaptive agricultural finance ecosystem.

Artificial Intelligence (AI) & Machine Learning (ML)

AI and ML are driving the Agri-Fintech revolution, allowing financial institutions and agritech companies to make informed financial decisions based on data. These technologies find special application in fields such as:

Credit Risk Forecast: AI algorithms can foretell the risk profile of specific farms by examining a synergy of satellite imagery, soil quality information, climatic conditions, and past crop yields. This makes lending more inclusive, even to farmers who lack credit history.

Crop Yield Prediction: Machine learning models utilize climatic and agronomic information to predict anticipated yields for various crops. These forecasts are imperative for assessing a farmer's ability to repay the loan, allowing lenders to customize loan amounts and tenors accordingly.

With AI and ML, lenders and insurers can underwrite farm risks more effectively, improve loan portfolios, and minimize default levels, thus making rural credit more scalable and sustainable.

Satellite Imagery & Remote Sensing

Satellite technology and remote sensing have added new horizons to Agri-Fintech. Banks and Fintech firms can now track fields of agriculture from space, which provides numerous benefits:

Field Monitoring: Satellite images enable real-time monitoring of crop health, planting patterns, and vegetation indices. This can be used to confirm whether the borrowed amount is being utilized efficiently and whether crops are developing as anticipated.

Insurance and Claims Processing: Remote sensing assists in evaluating actual field conditions during disasters such as floods or droughts. This allows for objective and prompt insurance claims payments, thereby minimizing disputes and delays.

Through the combination of geospatial information with financial services, Agri-Fintech platforms are increasingly transparent, risk-conscious, and farmer-focused.

Source:https://www.linkedin.com/posts/krishikan_agrifintech

Mobile Apps and IoT Integration

The ubiquity of smartphones in rural India has enabled mobile applications to become a potent force in Agri-Fintech. Through these apps, farmers have access to a variety of financial services at their fingertips, such as:

Loan Management and Tracking: Farmers are able to apply for loans, view loan status, plan repayments, and receive reminders—all via simple mobile interfaces.

Expense and Budgeting Tools: Certain apps assist farmers in monitoring input costs, projecting income, and controlling seasonal budgets to ensure financial discipline.

Furthermore, Internet of Things (IoT) devices are being integrated into fintech platforms with capabilities like real-time financial triggers. An example would be an irrigation sensor measuring drought stress triggering an automatic microloan offer or insurance notification..

5. Leading Agri-Fintech Innovations

The international Agri-Fintech ecosystem is experiencing an explosion of innovative solutions and early-stage startups that are revolutionizing the way farmers obtain financial and farm services. These innovations are using advanced technologies such as blockchain, AI, and mobile platforms to provide personalized, transparent, and inclusive services to rural populations. The following are some of the most significant developments: Joy *et.al.* 2024.

Successful Startups Driving Agri-Fintech Transformation

A number of startups worldwide are becoming important players in closing the gap between farmers and financial ecosystems. Such firms are providing end-to-end solutions that blend financial access, market connections, and agronomic assistance, specifically tailored to suit smallholder farmers' needs.

DeHaat (India): DeHaat has transformed rural agriculture by providing a single-platform solution that provides agri-inputs, customized advisory, market linkages, and financial services like loans and insurance. The platform employs digital technologies to link farmers directly with suppliers, customers, and financial services, improving profitability and cutting dependence on intermediaries.

TaniHub (Indonesia): TaniHub empowers farmers by linking them with markets and financial services using a digital platform. Through aggregating farmer produce and matching them with buyers, TaniHub also ensures access to working capital and agri-loans, allowing farmers to expand operations while guaranteeing fair prices.

FarmDrive (Kenya): Addressing financial exclusion, FarmDrive leverages smartphone data, such as mobile behavior and farming cycles, to create alternative credit scores for smallholder farmers. This solution allows banks to assess creditworthiness more efficiently and extend microloans to hitherto unbanked farmers.

Blockchain in Agri-Fintech

Blockchain technology is starting to emerge as a game-changer in Agri-Fintech through providing transparency, security, and automation in agri-transactions. Its decentralized nature provides assurance, traceability, and accountability in financial transactions, which are paramount for smallholder farmers as they mostly operate in informal markets.

Major uses of blockchain in Agri-Fintech are:

Clear Contract Farming: Blockchain provides immutable and verifiable records of contracts between buyers and farmers. This decreases the chances of contract disputes and ensures timely and equitable payment to farmers for their crops.

Traceable Subsidy Payment: Through the use of a blockchain to record government subsidy payments, governments can trace payments directly into the hands of intended beneficiaries. This eliminates leakages, enhances efficiency, and makes public schemes more trustworthy.

Smart Contracts for Input Purchase Agreements: Smart contracts—programmed self-executing agreements on the blockchain—release payments or delivery automatically once conditions are fulfilled. For instance, a payment to the farmer for seeds could be made only after verifying delivery, with each party held accountable.

Benefits of Agri-Fintech to Farmers

Agri-Fintech is emerging as a potent driver of rural livelihood change. Through the integration of digital finance and agricultural know-how, it equips farmers—especially smallholders and poorer segments of society—with means, information, and financial services previously out of reach. The outcome is an improved, more profitable, and productive farming community.

Direct Farmer Benefits

Agri-Fintech solutions provide an array of real-time, tangible advantages that streamline and enhance the manner in which farmers run their businesses and finances:

- Access to Finance in Remote Areas: Conventional bank services tend to be

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inaccessible to farmers in remote or underserved locations. Agri-Fintech fills this void through online lending platforms and mobile applications, making credit accessible even without the presence of physical bank outlets.

- Minimized Exploitation by Middlemen: Farmers are often exploited through unjustified prices and excessive interest informal loans. Online platforms provide direct connections to buyers, suppliers, and lenders, providing a more balanced transaction and cutting down on the reliance on intermediaries.
- More Effective Crop Planning with Data Backing: Through the use of AI-based advisory platforms and precision analytics, farmers can make smarter choices in terms of crop choice, planting time, and input deployment. This translates into improved yields and reduced input expenses.
- Faster Access to Crop Insurance and Claims: Digital insurance schemes enable farmers to register, remit premiums, and lodge claims with less paperwork and quicker turnaround. Satellite imagery and remote sensing also assist in rapid and precise measurement of crop damage, expediting compensation procedures.

Economic Impact on Farming Households

Agri-Fintech integration is fostering macroeconomic growth in rural areas by enhancing farmers' incomes through better access to credit, markets, and inputs via digital platforms. It boosts input use efficiency with precision tools that reduce costs and improve productivity. Additionally, AI-driven credit assessment and crop monitoring enable tailored loan products, reducing default rates and financial stress. Collectively, these advancements strengthen rural financial systems, encourage sustainable agriculture, and stimulate broader economic development in agrarian communities

6. Challenges and Barriers

While promising, Agri-Fintech adoption is confronted with a number of challenges. Low digital literacy among farm communities restricts the utilization of financial apps and tools efficiently. Inefficient internet and mobile connectivity in rural areas further limit usage. Trust deficiency in online platforms and fear of cyberattacks and data breaches also serve as key disincentives. Overcoming these issues demands strategic intervention in the form of training schemes, information campaigns, and public-private collaborations. Offering low-cost smartphones, subsidized data packages, and the construction of strong digital infrastructure are essential to make sure that the advantages of Agri-Fintech permeate all farmers equally and safely.

7. The Road Ahead

The future of Agri-Fintech is replete with potential to transform agriculture into a more resilient, intelligent ecosystem. Alignment with Climate-Smart Agriculture (CSA) will allow farmers to adjust to shifting weather patterns without sacrificing productivity and profitability. Online crop marketplaces with integrated finance and insurance modules will enable farmers to trade securely and confidently. Technologies such as Digital Twins will make possible the virtual simulation of farms, facilitating predictive analysis and improved risk management. With the growth of Agri-Fintech, its extension to other regions of the world will need region-specific tailoring to ensure that local requirements, languages, and problems are addressed adequately.

8. Conclusion

Agri-Fintech is transforming agriculture by combining finance and technology to bring about a more efficient, inclusive, and climate-resilient industry. It equips farmers with greater access to credit, insurance, and market insights. With continued innovation, facilitative policies, and investments in digital infrastructure and farmer education, Agri-Fintech can be a pillar for sustainable, profitable, and future-proof farming worldwide.

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References

Glavanits, J., & Szabo, T. (2024). FinTech Solutions Supporting Sustainable Agriculture? Lessons from Africa. *Proceedings of the Central and Eastern European eDem and eGov Days 2024*, 97-103.

Joy, I. S., Basher, F., Sultana, N., Tahmid, M. A., Akthar, S. R., Hasan, M., & Ahmed, S. (2024, July). Revolutionizing Agricultural Finance: Simplifying Farmer Access to Financial Tools with an Innovative Fintech Platform. In *2024 2nd World Conference on Communication & Computing (WCONF)* (pp. 1-8). IEEE.

Prajapati, M. R., & Singh, R. (2023). Revolutionizing agricultural finance: The rise of agrifintech. *Recent Advances in Agricultural Sciences and Technology*, *2021*, 22.

Rayhan, M. J., Rahman, S. M., Mamun, A. A., Saif, A. N. M., Islam, K. A., Alom, M. M., & Hafiz, N. (2024). FinTech solutions for sustainable agricultural value chains: A perspective from smallholder farmers. *Business Strategy & Development*, *7*(2), e358.

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