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MINIMUM SUPPORT PRICE IN INDIA: FROM PRICE ASSURANCE TO INCOME SECURITY

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Introduction

Every year, the government sets the Minimum Support Price (MSP) for major Kharif and Rabi crops before sowing the seed assuring farmers a remunerative price for their agriculture output. The Minimum Support Price (MSP) is the official price by the Government of India to procure crop produce from farmers, regardless of market fluctuations. It is a policy tool aimed at ensuring price security, encouraging diversified crop production, and shielding farmers from the uncertainties of open markets. By doing this govt aims to stop the distress sale of the produce and there by eradicate the farmer suicides. But in recent years, MSP has become a flashpoint in debates around agricultural reforms and farmers rights.

Evolution of MSP

The MSP system under the agriculture ministry began in 1966-67 with the procurement of wheat and paddy during the green revolution era to support food security and prevent farmers from distress sale. Today, the Commission for Agricultural Costs and Prices (CACP) recommends MSP for 25 major agricultural commodities of 22 crops and fair and remunerative price for sugarcane crop is determined by the department of food and public distribution and for other listed crops the cabinet committee on economic affairs chaired by the Prime Minister is the approval committee of MSP for kharif and rabi crops, it includes cereals, pulses, oilseeds, and commercial crops (GoI, 2018).

Why MSP Matters to Farmers

Price assurance: Farmers are aware of the least amount of income they will get under the MSP even when the market crashes on their commodities. This assists them in budgeting their money, repayment of loans and investment in the subsequent cropping season without the fear of price fluctuations. It creates confidence in the farming system and lessens the reliance on the local money lenders, middlemen and exploitative market practices.

Prevents distress sales: Especially critical during bumper harvests or gluts. When market prices crash due to overproduction, MSP will enable farmers not to sell their produce at less than the cost of production. This ensures that farmers do not lose money after investing in inputs like seeds, fertilizers, and labour.

Features of MSP

Government guarantee: Government of India assuring the farming community of buying the various crops declared under the MSP so as to minimize the farmers distress sales.

Livelihood stability: MSP provides a safety net to small and marginal farmers. MSP therefore provide a much-needed cushion against low market price as more than 85 per cent of Indian farmers fall in this category. It minimizes the uncertainty of income and rural indebtedness thus enhancing quality of life and mental well-being.

Crop coverage: MSP is announced for different variety of crops it includes cereals, pulses, oilseeds and commercial crops to promote the crop diversification and reduce the mono cropping patterns.

Announcement before sowing season: The government declares MSP for various crops ahead of the sowing season, which helps the farmers to make better decisions regarding the cultivation of specific crops that can give them higher profits.

Cost consideration: MSP is determined based on the factors such as cost of production, market trends, changes in input prices, demand and supply and food inflation etc.

Buffer stock maintenance: The government frequently procures crops from farmers at MSP to build food stocks, and used to ensure food security and support the Public Distribution System (PDS).

Inflation control: By maintaining a steady supply of agricultural produce and preventing market price collapses, MSP helps stabilize food prices for consumers.

Challenges of MSP

No legal guarantee: Currently, MSP is only a declared price and not enforceable in private market transactions. Without legal backing, farming communities were forced to sell at lower rates due to weak bargaining power and poor procurement infrastructure. Farmers demand that MSP be made legally enforceable, but the government argues it could distort markets (Jana *et al.*, 2024).

Poor procurement infrastructure: Due to the lack of well-established procurement centres across the nation limits the MSP benefits. While states like Punjab and Haryana benefit from robust procurement, farmers in eastern and southern states often do not receive MSP, and left behind due to poor procurement infrastructure (TOI-2025). Farmers in these areas often sell at below-MSP rates due to poor infrastructure and weak market access.

Crop bias: MSP primarily favours wheat and paddy, creating a skewed incentive structure. This has led to mono-cropping, neglecting pulses, oilseeds, and millets, causing groundwater depletion and soil nutrients (ICRIER-2024). It discourages diversification into pulses, millets, and oilseeds, which are more sustainable and nutritious.

MSP calculation disputes: Demand of the farmers that the MSP should be calculated based on C2 cost (comprehensive cost), It accounts for the estimated value of family labour, rental value of owned land, and interest on owned capital, but CACP often uses cost A2+FL (cost A2 these are the expenses farmers directly incur from their own pocket for purchasing inputs such as seeds, fertilizers, pesticides, hired labour, and even leased land, FL= Family labour). As a result, the farmers felt that the declared MSP may not reflect fair compensation or ensure profitability for many smallholders. The increase in MSP for mandated crops is in line with the 2018-19 budget decision to set support prices at least 1.5 times the all-India weighted average cost of production, ensuring farmers receive at least a 50 per cent profit margin over their input costs (CACP-2025).

Way forward

Diversified Procurement - States must step up to procure more pulses, oilseeds, and coarse grains under MSP to encourage diversified crop production.

Improve Awareness & Infrastructure - Expansion of procurement centres, digital payment systems, and farmer education is crucial to reach out the procurement centres.

MSP coverage of different crops

Crop category	Examples
Cereals	Paddy, Maize, Wheat, Jowar, Bajra, Barley and Ragi
Pulses	Tur, Moong, Urad, Gram, Masur
Oil seeds	Groundnut, Sunflower, Soyabean Sesamum Niger seed, Rapeseed/mustard and safflower
Other crops	Sugarcane, Cotton, Jute and Copra

Support Prices Declared for Kharif Crops: 2025 - 26 Marketing Season

Crops		MSP 2025-2026 (Kharif)
Paddy	Common	2369
	Grade A	2389
Jowar	Hybrid	3699
	Maldandi	3749
Bajra		2775
Ragi		4886
Maize		2400
Tur/Arhar		8000
Moong		8768
Urad		7800
Groundnut		7263
Sunflower		7721
Soyabean		5328
Sesamum		9846
Nigerseed		9537
Cotton	Medium staple	7710
	Long staple	8110

Source: CACP-2025

Conclusion

MSP is not just a price; it is a symbol of trust between the farmer and the state. While it has saved millions from ruin, it also needs urgent reform and rethinking. In the journey toward sustainable and inclusive agriculture, MSP must evolve from a price safety net to a comprehensive income support system.

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THE POTENTIAL OF POLYHALITE-A MULTI-NUTRIENT FERTILIZER FOR SUSTAINABLE AGRICULTURE

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Abstract

Polyhalite, a naturally occurring mineral fertilizer, is gaining attention as a sustainable solution for balanced crop nutrition. Composed of potassium, calcium, magnesium and sulfur in plant-available sulfate forms, polyhalite offers a multi-nutrient advantage over conventional fertilizers. Its slow-release nature improves nutrient uptake efficiency and reduces losses, while also enhancing soil structure and long-term fertility. Ideal for chloride-sensitive crops, it supports a wide range of farming systems, including organic agriculture. Despite challenges like limited regional availability and farmer awareness, polyhalite holds significant promise for improving crop productivity and supporting sustainable nutrient management.

Keywords : Polyhalite, nutrient uptake, organic agriculture, nutrient management

Introduction

In the quest for sustainable and efficient nutrient management, polyhalite is emerging as a valuable natural fertilizer. This mineral, mined from evaporite deposits, is a rich source of essential nutrients, including potassium, magnesium, calcium, and sulfur, making it a one-stop solution for balanced crop nutrition (Vale and Sérgio, 2017). Its unique properties and multi-nutrient composition position polyhalite as a game-changer in modern agriculture.

What is Polyhalite?

Polyhalite is a naturally occurring mineral with the chemical formula $K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$. It is composed of four vital nutrients:

- **Potassium (K):** Essential for water regulation, enzyme activation, and overall plant growth.
- **Calcium (Ca):** Improves cell wall strength, nutrient transport, and soil structure.
- **Magnesium (Mg):** A key component of chlorophyll and crucial for photosynthesis.
- **Sulfur (S):** Vital for protein synthesis and improving crop quality.

Polyhalite's multi-nutrient nature provides a balanced supply of these nutrients, supporting the growth of a wide range of crops.

POLYHALITE
MINERAL FERTILIZER



$K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$

K Potassium Calcium
Ca Magnesium Sulfur

CHALLENGES FACES
Limited regional availability

SUSTAINABLE SOLUTION FOR BALANCED CROP NUTRITION

- Multi-nutrient advantage over conventional fertilizers
- Slow-release nature improves nutrient uptake efficiency
- Suitable for chloride-sensitive crops
- Support for organic systems and diverse farming systems

IMPROVES CROP PRODUCTIVITY

- Enhances soil structure and long-term fertility
- Limited regional availability and farmer awareness

Why to Choose Polyhalite?

Polyhalite stands out as an exceptional choice for modern agriculture due to its multi-nutrient composition and unique benefits. Unlike conventional fertilizers that provide one or two nutrients, polyhalite delivers four essential nutrients-potassium, magnesium, calcium, and sulfur-in a single application, simplifying nutrient management for farmers. Its slow-release nature ensures a steady supply of these nutrients, reducing losses through leaching and enhancing their uptake efficiency by plants. Additionally, polyhalite contributes to soil health by improving soil structure and nutrient retention, thereby promoting long-term fertility (Bhatt *et al.*, 2024). As a natural mineral with low chloride content, it is environmentally friendly and ideal for chloride-sensitive crops such as potatoes, tomatoes, and strawberries, making it a versatile and sustainable solution for diverse agricultural systems.

Impact on Crop Growth and Productivity

Polyhalite enhances crop performance by providing a balanced supply of macro and secondary nutrients. Potassium and magnesium improve photosynthetic efficiency, while calcium strengthens cell walls, leading to robust plant growth. Sulfur enhances protein synthesis and boosts crop quality. Studies have shown that polyhalite improves yield and quality in crops like cereals, oilseeds, fruits, and vegetables, making it a versatile solution for diverse farming systems.

Applications in Agriculture

Polyhalite can be applied directly to the soil or blended with other fertilizers to create customized nutrient formulations. It is effective across a wide range of soil types and crop systems, including field crops, horticultural crops, and plantations. Its versatility makes it suitable for use in both conventional and organic farming practices.

Challenges and Future Prospects

While polyhalite offers numerous benefits, its adoption is limited by regional availability and the lack of awareness among farmers. Efforts to expand its accessibility and educate farmers on its benefits are critical for its widespread use. Research into optimizing application rates and understanding its interaction with different soil types will further enhance its value.

Conclusion

Polyhalite represents a sustainable and efficient nutrient source for modern agriculture. Its ability to supply multiple essential nutrients, improve soil health, and boost crop productivity makes it a valuable addition to nutrient management strategies. By incorporating polyhalite into farming systems, growers can achieve better yields, improved crop quality, and enhanced sustainability.

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AGRICULTURAL ECONOMICS: A PILLAR OF FOOD SECURITY

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Introduction

Food security means having reliable access to sufficient and nutritious food. As populations rise and climate change strains production, agricultural economics is vital—it helps design policies, guide investments, and optimize resource use to ensure everyone eats well

Understanding Agricultural Economics

A discipline combining economics and farming, agricultural economics:

- Allocates resources (land, labor, capital) efficiently for max output
- Provides price forecasts and risk analysis to stabilize farm incomes
- Evaluates policy impacts—like subsidies, tariffs—for equitable, sustainable agricultural growth

Securing Food Availability

At its core, food security depends on consistent production:

- Boosting productivity through improved seeds, irrigation, and agro-tech
- Scaling the Green Revolution's lessons—using high-yield maize and wheat while avoiding environmental harm
- Emphasizing sustainable practices especially in vulnerable areas

Improving Access & Stabilizing Prices

Even if food exists, it must be affordable and accessible:

- Market information systems (e.g., mobile alerts in India/Niger) reduce price volatility and inform farmers
- Safety nets, like India's Public Distribution System under the National Food Security Act, ensure millions receive subsidized grains
- Trade policies—tariffs, quotas—must balance domestic protection with consumer access and global supply stability

Managing Risks & Shocks

Food systems face weather, price, disease, and conflict risks:

- Agricultural economists design **insurance schemes**, buffer stocks, and policy tools to cushion farmers
- They also build **early warning** models and assess the impact of financialized commodity markets on food access

Promoting Sustainability & Equity

Long-term food security requires wise stewardship:

- Environmental economics shapes regulations on soil, water, and agrochemical use
- Emphasis on gender equity is crucial: closing the gender gap in land, credit, and tech access can raise output by up to 30%
- Diversification—crop rotations, agroforestry—reduces ecological risks and boosts nutrition

Harnessing Technology & Innovation

Modern agri-economics blends finance with tech advancement:

- Advocates for precision agriculture: drones, AI, IoT improve yield and resource use
- Supports R&D investments—breeding climate-resilient crops and developing local solutions to adapt to changing conditions

Case Studies & Global Initiatives

- AMIS (FAO, G20): supports transparency and coordination during price shocks
- CGIAR programs in Africa and Asia improve seeds, practices, and farmer incomes to combat hunger
- Regional research (e.g., USDA's EFSNE) shows local production systems improve access for vulnerable communities

Challenges Ahead

- Underfunded R&D: public agricultural research spending lags—impacts yield growth
- Climate finance gaps: insufficient support for small-scale farmers facing climate shocks
- Market speculation: financialization of commodity markets can raise food prices in poorer countries

Conclusion

Agricultural economics plays a central role in sustainable food security by:

- Enhancing production through optimal resource use and innovation
- Stabilizing markets and improving access for urban and rural poor
- Managing risks and building resilient systems
- Driving fairness by supporting gender inclusion and environmental care

Addressing challenges will require stronger public investment in R&D, improved climate financing, better market regulation, and targeted policies for marginalized farmers. Yet the tools of agricultural economics offer a proven path toward a world free from hunger.

Further Reading & References

- Role of agricultural economics and policy analysis
- Gender equity in farming boosts productivity
- Precision agriculture's impact on food security
- R&D investments and climate adaptation urgency
- Financialization and market risks
- Global market systems like AMIS

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INDIA'S NEXT BIG TRAVEL TREND: THE RISE OF AGRITOURISM

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Introduction

Agro-tourism, or agri-tourism, refers to travel experiences centered around agricultural activities. Visitors engage with farms, orchards, plantation and rural lifestyles experiencing a slice of countryside life. Whether it's a day trip to a vineyard or a week-long stay on an organic farm, agro-tourism offers educational and recreational activities tied to farming and rural heritage.

Agro-tourism bridges the gap between farmers and urban dwellers, fostering appreciation, awareness and rural revitalization.

Agro-tourism Benefits

For Farmers:

- A **new income stream** beyond crop sales
- Direct marketing of farm products like honey, ghee, and handicrafts
- **Pride and value** in rural knowledge and traditional practices

For Tourists:

- A break from concrete jungles
- Connection with the origins of food
- Cultural immersion in local festivals, crafts and cooking

For Rural Communities:

- Job creation for youth and women
- Revived folk traditions
- Improved infrastructure (roads, sanitation, internet access)

Significance and Impact

According to the **Ministry of Tourism, Government of India**, rural tourism (including agro-tourism) is gaining momentum under initiatives such as '**Swadesh Darshan**' and '**Dekho Apna Desh**'. A study by the **Indian Council of Agricultural Research (ICAR)** highlighted that agro-tourism has the potential to increase farm income by **20–30%** for participating households.

In Maharashtra, agro-tourism has shown measurable impact:

- Over **350 registered agro-tourism centers** across the state
- An estimated **annual footfall of 1.5 million tourists**
- Employment generation for more than **5,000 rural youth and women**

Moreover, global trends show promise. The **World Tourism Organization (UNWTO)** recognizes agro-tourism as a key instrument for achieving the **UN Sustainable Development Goals (SDGs)**, particularly SDG 8 (Decent Work and Economic Growth) and SDG 11 (Sustainable Cities and Communities).

Case Studies

1. Baramati Agro-Tourism Development Corporation, Maharashtra

Established by Pandurang Taware, Baramati Agro-Tourism is widely regarded as a pioneer in India's agro-tourism movement. Through immersive experiences such as sugarcane juicing, bullock-cart rides, and rural games, the center receives more than **80,000 visitors annually**. It also conducts **training programs for farmers** interested in replicating the model. The initiative has directly contributed to:

- **Employment for over 300 locals**
- **A 30% increase in local farm product sales**
- Creation of an agro-tourism cluster with **over 200 affiliated farms**

2. Spice Plantation Tourism, Kerala

Kerala's Western Ghats region offers tourists spice tours focused on the cultivation of black pepper, cardamom, and nutmeg. Popular destinations such as Thekkady have integrated agro-tourism with Ayurveda and culinary experiences. These initiatives have improved the **seasonal tourism demand** and expanded revenue streams for plantation owners.

3. Binsar Eco-Camp, Uttarakhand

Located in the Binsar Wildlife Sanctuary buffer zone, this initiative combines farm-based tourism with biodiversity conservation. Tourists participate in organic farming, composting, and rural lifestyle activities. The camp operates on a **community-managed model** and contributes to environmental education and employment in remote Himalayan villages.

Challenges to Growth

Challenge	Implication
Lack of Infrastructure	Limited road access, sanitation, and digital connectivity
Skill Gaps	Farmers require training in hospitality, marketing, and safety
Policy Fragmentation	Lack of national-level agro-tourism policy or framework
Environmental Concerns	Risk of over-commercialization without ecological safeguards

To overcome these, states like Maharashtra and Kerala have introduced specific **agro-tourism policies** offering subsidies, training, and marketing support. However, replication across other regions remains limited. To overcome these, states like Maharashtra and Kerala have introduced specific **agro-tourism policies** offering subsidies, training, and marketing support. However, replication across other regions remains limited.

Future Outlook and Policy Direction

Agro-tourism is increasingly being integrated into rural development and livelihood diversification programs. Key recommendations for scaling its impact include:

- **Capacity Building:** Through institutions like Krishi Vigyan Kendras (KVKs) and ATDCs
- **Financial Incentives:** Soft loans, tax benefits, and insurance schemes for farm-stay operators
- **Digital Promotion:** Leveraging online platforms and social media to attract younger tourists
- **Certification Standards:** Ensuring quality, hygiene, and safety compliance

Furthermore, the **Agro-Tourism Policy 2020 by Maharashtra** has been lauded as a model framework, offering up to **₹25 lakh in capital assistance** for eligible agro-tourism entrepreneurs.

Conclusion

Agro-tourism represents a transformative model for achieving inclusive rural development, sustainable livelihoods, and cultural preservation. By turning farms into learning landscapes and rural homes into experience centers, agro-tourism can unlock new economic and social possibilities. With the right policy support, investment, and capacity building, India stands poised to become a global hub for farm-based tourism that is not only profitable but also purposeful.

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AGRO-TOURISM IN INDIA: RECONNECTING URBAN LIVES WITH RURAL HERITAGE

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Introduction

As urbanization and industrialization rapidly reshape modern life, there is a growing yearning among city dwellers to reconnect with nature and traditional lifestyles. This has paved the way for agro-tourism, a sustainable and innovative model that combines agriculture with tourism to revitalize rural economies, educate the public, and promote cultural exchange (Vishwanath *et al.*, 2022). In India, where agriculture forms the backbone of the rural economy, agro-tourism holds immense potential for income diversification and rural development.

What is Agro-Tourism?

Agro-tourism, also known as agricultural tourism or farm tourism, involves opening up agricultural operations to tourists for recreational, educational, or experiential purposes. Visitors engage in farm-related activities, such as harvesting, milking, ploughing with bullocks, or participating in folk traditions, while farmers benefit from additional income, market exposure, and socio-cultural interaction (Sahoo *et al.*, 2023; Krishna, 2019).

Why Agro-Tourism in India?

India's diverse agro-climatic zones, rich biodiversity, cultural heritage, and traditional knowledge systems make it uniquely suited for agro-tourism. Small and marginal farmers, who form over 85% of the total farming population, can leverage this model to reduce dependence on crop income alone. Agro-tourism offers:

- **Supplementary income** during off-season or drought years
- **Preservation of indigenous knowledge** and cultural practices
- **Promotion of sustainable farming** through awareness
- **Increased value addition** via local crafts, organic products, and home-stays (Kothari and Perwej, 2021)

Key Components and Activities

Agro-tourism is multidimensional and may include:

- **Farm stays:** Visitors live in traditional village homes or specially designed guesthouses within farms, experiencing rural life firsthand.
- **Interactive farming:** Hands-on activities like planting, weeding, harvesting, irrigation, and composting.
- **Animal care:** Feeding livestock, collecting eggs, milking dairy animals, or even riding bullock carts (Sahoo *et al.*, 2023).
- **Farm-to-table food experiences:** Guests are served fresh meals prepared from farm produce, often using traditional cooking methods.

- **Cultural immersion:** Folk music, local dances, storytelling, handicraft workshops, and participation in rural festivals.
- **Educational tours:** Learning modules for students and urban families on sustainable farming, biodiversity conservation, and rural livelihoods (Vishwanath *et al.*, 2022).



Bullock Ride (source: Saguna Baug website)



Water Buffalo Ride (source: Saguna Baug)



Milking of a Cow (source: Saguna Baug website)

Ecological and Educational Benefits

Agro-tourism promotes environmental awareness by showcasing eco-friendly farming methods such as organic cultivation, natural pest control, permaculture, and water harvesting (Mansor *et al.*, 2015). It offers a platform for dialogue on food security, climate-resilient agriculture, and biodiversity conservation. For children and youth, agro-tourism serves as a living classroom where they learn about the origins of food, the importance of respecting natural resources, and the value of manual labour. In an era of digital saturation, such real-world exposure enhances empathy, environmental literacy, and community engagement.

State-Level Initiatives and Models in Agro-Tourism Across India

Maharashtra has been a pioneer in promoting agro-tourism, becoming the first Indian state to institutionalize it through the establishment of the *Agro-Tourism Development Corporation (ATDC)* in 2005. The state operates a flagship 28-acre pilot project in Baramati, Pune, and currently supports over 328 agro-tourism centres spread across 30 districts. Notable examples include vineyard-based agro-tourism experiences in Nashik and Pune, and mango orchard visits in coastal districts like Ratnagiri and Raigad (Krishna and Sahoo, 2020).

Karnataka offers plantation-based agro-tourism, particularly in Coorg, where tourists engage in immersive experiences within coffee estates, participating in various stages of coffee production—from harvesting to processing and brewing (Anonymous, 2025).

Kerala has institutionalized agro-tourism through the *Kerala Agro-Tourism Network*, enabling visitors to explore aromatic and spice gardens. The program educates tourists on spice cultivation techniques and facilitates the purchase of organically grown spices directly from farms (Anonymous, 2025).

Sikkim, recognized as India's first fully organic state, integrates agro-tourism with sustainable farming practices. Tourists are offered guided farm visits, hands-on exposure to ecological agriculture, and opportunities for interaction with organic farmers (Anonymous, 2025).

Punjab emphasizes cultural agro-tourism by offering experiences such as tractor rides, traditional rural cuisine (e.g., *sarson da saag* and *makki di roti*), and folk performances, thereby preserving and promoting the agrarian heritage and rural lifestyle of the state (Anonymous, 2025).

Challenges to Address

Despite its potential, agro-tourism in India faces several constraints:

- **Infrastructure gaps:** Poor road connectivity, limited sanitation, and weak internet access in rural areas (Shah and Dave, 2020).
- **Lack of awareness:** Many farmers are unaware of the commercial potential of tourism.
- **Training needs:** Skills in hospitality, communication, and digital marketing are often missing among rural communities (Kothari and Perwej, 2021).
- **Policy and financing hurdles:** Absence of specific policies and financial schemes tailored for agro-tourism ventures.

Policy Interventions and Way Forward

To boost agro-tourism, state and central governments need to formulate clear policies integrating agriculture, tourism, and rural development. Financial institutions must offer soft loans and insurance products customized for agro-tourism entrepreneurs. Capacity-building programs involving Krishi Vigyan Kendras (KVKs), agricultural universities, and tourism departments can train farmers in hospitality management, eco-tourism standards, and digital outreach. Marketing support through state tourism websites, travel expos, and collaboration with tour operators is equally vital.

Conclusion

Agro-tourism is more than a leisure activity and it is a grassroots development strategy that revives rural culture, strengthens farm economies, and bridges the rural-urban divide. It brings the story of agriculture alive for the modern consumer and creates new possibilities for farmers beyond their fields. As India strives for inclusive and sustainable rural development, agro-tourism offers fertile ground for innovation, income, and intercultural harmony.

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PRESSMUD – A SUSTAINABLE AMENDMENT FOR SOIL HEALTH AND CROP PRODUCTIVITY

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Abstract

Pressmud, a nutrient-rich by-product of the sugarcane industry, is gaining recognition as a sustainable soil amendment in modern agriculture. Rich in organic matter, macro- and micronutrients, and beneficial compounds, pressmud enhances soil fertility, structure, and biological activity. Its application improves soil physical and chemical properties, boosts nutrient cycling, and increases crop yield and quality across diverse cropping systems. Furthermore, pressmud offers significant environmental advantages by recycling agro-industrial waste and reducing the reliance on synthetic fertilizers. While its use must be managed carefully to avoid potential issues like nutrient imbalance or odor, pressmud holds considerable promise for promoting sustainable agricultural productivity and long-term soil health.

Keywords : Pressmud, soil fertility, nutrient cycling

Introduction

Pressmud, a by-product of the sugarcane industry, is increasingly recognized for its potential to enhance soil fertility and boost crop yields (Kumar *et al.*, 2017). Rich in organic matter and nutrients, pressmud serves as an excellent soil amendment, offering a sustainable alternative to synthetic fertilizers. Its application not only improves soil properties but also supports long-term agricultural productivity, making it an eco-friendly choice for modern farming.

What is Pressmud?

Pressmud, also known as filter cake, is the residual material left after the clarification of sugarcane juice during sugar production (Fantaye *et al.*, 2016). It is a nutrient-rich organic substance containing significant amounts of nitrogen (N), phosphorus (P), potassium (K), calcium and organic carbon. In addition, it is a valuable source of micronutrients and organic acids that benefit soil and plant health.

Impact of Pressmud on Soil Properties

Pressmud has a significant impact on soil properties, making it a valuable amendment for improving soil health. It enriches soil organic carbon, which enhances soil

PRESSMUD ORGANIC FERTILIZER



**FILTER CAKE, BY-PRODUCT
OF SUGARCANE PROCESSING**

VALUABLE RESOURCE

Appropriate application
practices necessary

IMPROVES SOIL STRUCTURE, NUTRIENT CONTENT, WATER RETENTION AND MICROBIAL ACTIVITY

- Better root growth and higher crop yields
- Neutralizes soil acidity supports long-term soil fertility

REDUCES DEPENDENCE ON CHEMICAL FERTILIZERS

- Promotes eco-friendly farming

structure, porosity, and aeration, creating an ideal environment for root growth. With its high nutrient content, pressmud supplies essential macro and micronutrients, boosting soil fertility and promoting efficient nutrient cycling. The organic matter in pressmud improves soil aggregation, increasing the soil's water-holding capacity, particularly in sandy soils prone to moisture loss. Additionally, the lime content in pressmud helps neutralize soil acidity, fostering a favorable pH balance for plant growth. Furthermore, its organic content stimulates microbial activity, encouraging nutrient mineralization and the decomposition of organic matter, which are crucial for maintaining long-term soil productivity.

Boosting Crop Yield and Quality

Pressmud application has been shown to enhance crop productivity by providing a balanced nutrient supply and improving soil conditions. Crops grown in pressmud-amended soils exhibit better root development, increased nutrient uptake, and higher resilience to environmental stresses. The improved soil health leads to higher yields and better crop quality in cereals, vegetables, sugarcane, and horticultural crops.

Environmental Benefits of Pressmud

Pressmud contributes to sustainable farming by reducing dependency on chemical fertilizers and providing a waste recycling solution for the sugar industry. Its organic nature minimizes the environmental risks associated with synthetic inputs, such as nutrient runoff and soil degradation.

Challenges and Considerations

Despite its benefits, the application of pressmud requires careful management. Overuse can lead to nutrient imbalances, and improper handling may cause odor issues or contamination. Farmers need to follow recommended application rates and guidelines to optimize its benefits and avoid potential drawbacks.

Conclusion

Pressmud serves as a valuable resource for improving soil health and crop productivity, aligning with the goals of sustainable agriculture. Its ability to enhance soil properties, support plant growth, and contribute to environmental sustainability makes it an essential amendment for modern farming systems. By integrating pressmud into nutrient management practices, farmers can achieve higher yields, healthier soils, and a more sustainable future.

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AGRO-WASTE TO ADDITIVE: A SUSTAINABLE APPROACH TO FOOD ENHANCEMENT

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Introduction

Agricultural and food wastes are significant global issues impacting the environment, economy, and society. Food loss occurs throughout the supply chain due to decisions made by suppliers, while food waste is primarily attributed to retailers, food service providers and consumers. Rapid population growth and consumption behaviour contribute to this problem. Environmental impacts are exacerbated by food loss during production. Approximately 1.3 billion tons of food are lost or wasted annually, amounting to one-third of food produced for human consumption and utilizing nearly 30% of agricultural land (Annon., 2021). Different regions exhibit varying patterns of food waste and loss, with industrialized countries experiencing more waste in later supply chain stages, while developing countries face challenges at earlier stages due to inadequate infrastructure.

Novel approaches for the valorization of agricultural food wastes/byproducts

- **Valorization methods of agricultural food wastes/byproducts**

Food waste can be transformed into valuable products such as fine chemicals, nutraceuticals, antioxidants, bioactives, and biopolymers. Traditional disposal methods like landfilling and incineration present environmental, economic, and social issues, encouraging alternative valorization approaches. Extracted specialty chemicals are vital for nutraceutical and biomaterial use. Integrated biochemical, chemical, and physical methods enable the selective recovery of compounds while meeting regulatory standards and consumer expectations. (Plazzotta and Manzocco, 2019). Utilizing renewable resources and carbon from waste streams is essential for sustainable industrial development, achieved through green chemical processes, integrated biorefining, and biotechnological approaches.

- **Biorefinery for agricultural food wastes/by products**

Valorizing byproducts like agricultural residues, food processing waste, and food residuals can boost the global bioeconomy. The biorefinery approach promotes recycling food waste into energy and commercial products. Biotechnological methods such as anaerobic digestion, fermentation, and composting convert low-cost biomass into biofuels, biofertilizers, bioplastics, secondary chemicals, and biobased adsorbents for wastewater treatment. (Nayak and Bhushan, 2019). Using food waste in chemical synthesis fosters a closed-loop economy, cutting greenhouse gas emissions and reducing environmental impact compared to disposal. Recent initiatives, like the EU's renewable energy policy on waste-derived biofuels, emphasize biorefineries' role in building a sustainable society (Isah and Ozbay, 2020). In conclusion, food waste management through biorefineries offers environmental benefits by reducing emissions, easing environmental burdens, and decreasing reliance on fossil fuels.

Biofuel, derived from biomass and its refined products, has been utilized throughout human history for activities like cooking, lighting, and heating. With growing concerns about petroleum and coal-

based fuels, biofuel production is gaining global support. Countries like Denmark, Finland, and Sweden are increasingly utilizing food waste for biofuel production, including biodiesel, bioethanol, and biogas (Isah and Ozbay, 2020). Biodiesel, produced from plant oils through transesterification, can be made from low-cost food waste. Biogas, a renewable energy source, is generated via anaerobic digestion of biomass and upgraded with physicochemical and biological methods. Studies have explored techniques like ultrasound pretreatment and solid-state microanaerobic digestion to boost biogas production from food waste. Bioalcohol, particularly ethanol, is another biofuel produced through microbial fermentation of feedstocks like fast food waste. Biochar, created through pyrolysis, is used for soil amendment, environmental management, and energy storage in supercapacitors. Overall, biofuels provide sustainable alternatives to fossil fuels, utilizing renewable resources for a greener energy future (Nayak and Bhushan, 2019).

Single-cell protein, extracted from microbial biomass like bacteria, yeast, algae, and fungi through microbial fermentation, serves as an alternative and cost-effective protein source in human and animal diets. It addresses concerns related to protein scarcity, offering nutritional benefits and reducing costs in food and fodder formulation by utilizing bioconversion products from agricultural and industrial waste. Insects like black soldier fly larvae have been employed to valorize residual biomasses, converting organic wastes into high-quality animal feed and grass fertilizers (Anupama and Ravindra, 2000). Biopolymers, another important product derived from food wastes, find applications in various industries due to their biodegradability and biocompatibility. Bioplastic production from food waste, including poly hydroxy alkanoates (PHA) and poly hydroxy butyrate (PHB), contributes to waste reduction while offering environmentally friendly alternatives to conventional plastics (Leni *et al.*, 2021).

Table 1. Few examples of extracted valuable compounds from agricultural food wastes and byproducts

Agricultural food waste/ byproduct	Extracted valuable compounds
Kiwi juice pomace	Flavan-3-ol content and ascorbic acid content (total polyphenol content: $4.8 \pm 0.1 \text{ mg}_{\text{gae}} \text{ g}^{-1}$, total flavonoid content: $1.38 \pm 0.01 \text{ mg cat g}^{-1}$, ascorbic acid content: $120.6 \pm 0.5 \text{ mg } 100 \text{ g}^{-1}$)
Pistachio hard shells	Gallic acid, monogalloylglucose isomer, pentagalloylglucose, and kaempferol (total phenolic content ($332 \pm 11 \text{ mg}_{\text{gae}}/\text{g}$), total flavonoid content ($376 \pm 22 \text{ mg}/\text{categ}$), antioxidant activity by dpsh, teac, and orac ($6.1 \pm 0.9 \text{ } \mu\text{g}/\text{ml}$, $4001 \pm 7.5 \text{ } \mu\text{mol te}/\text{g}$, $879 \pm 17 \text{ } \mu\text{mol te}/\text{g}$, respectively)
Tomato processing waste	Lycopene ($76.87 \text{ mg}/\text{kg}$ dry weight), β -carotene ($6.12 \text{ mg}/\text{kg}$ dry weight)
Beetroot waste	Total phenolic content ($7 \pm 1 \text{ mg}_{\text{gae}} \text{ g}_{\text{extract}}^{-1}$) bioactive compounds (the most abundantly detected phenolic compounds: ferulic acid, vitexin, and sinapaldehyde)
Grape pomace	Recovery of anthocyanins $\rightarrow 45\%$, total phenolic content ($6.68 \pm 0.05 \text{ mg}_{\text{gae}} \text{ g}^{-1}$ (dry basis), total monomeric anthocyanins ($1.32 \pm 0.03 \text{ mg malvidin-3,5-diglycoside g}^{-1}$ (dry basis), antioxidant activity by abts and dpsh ($23.84 \pm 0.57 \text{ } \mu\text{molte g}^{-1}$ (dry basis), and $33.27 \pm 2.00 \text{ } \mu\text{molte g}^{-1}$ (dry basis) respectively

Agricultural food waste/ byproduct	Extracted valuable compounds
Rice bran	Oil (the yields 22% for conventional soxhlet extraction and 13%–14.5% for subcritical co ₂ soxhlet extraction) 76 nearly 10 times more thermolabile compounds, such as tocopherols (45.40–64.37 µg/g of oil), tocotrienols (157.89–198.31 µg/g of oil), and oryzanols (1.33–2.18 mg/g of oil), lower free fatty acid and peroxide values in extracted oil
Wheat bran	Arabinoxylan (the experimental yield (142.6 mg/g of wheat bran)
Broccoli stalk	Extracted pectin (the main neutral sugars: rhamnose and galactose, homogalacturonan and rhamnogalacturonan i substituted with β-1,4- d-galactan detected) 79 75% galacturonic acid with a degree of methyl-esterification of 56%, and an acetyl content of 1.1% found in the pectin fraction (yield 18%)
Banana peels	Pectin (the highest yield 17.05% dry basis) 81 characteristics of extracted pectin from ripe banana peels using 0.5 n hcl for 3 h (moisture content (10.00%), ash (11.15%), methoxyl content (6.40%), anhydrouronic acid (57.32%), and degree of esterification (63.37%)) characteristics of extracted pectin from unripe banana peels using 0.5 n hcl for 3 h (moisture content (14.13%), ash (13.83%), methoxyl content (5.25%), anhydrouronic acid (39.68%), and degree of esterification (75.03%))
Kiwi seeds	Oil (the highest yield 28.9 oil/seed wt %) 83 composition of extracted oil (total saturated fatty acids (8.94%), total monounsaturated fatty acids (14.79%), and total polyunsaturated fatty acids (76.27%)) the presence of off-flavors in oil samples
Citrus peels	Essential oil from navel navelate oranges (monoterpenes, oxygenated monoterpenes, and sesquiterpenes) chemical composition of essential oil from navel navelate oranges by conventional hydrodistillation (monoterpenes (98.56%) and oxygenated monoterpenes (0.14%))

Source: Capanoglu *et al.*, 2022

Conclusion

Food waste offers a valuable resource to address economic, social, and environmental challenges through its use in food formulations, as it contains essential nutrients and functional compounds (Capanoglu *et al.*, 2022). Drying processes are vital for ensuring microbial safety during valorization. Government support is key for developing technologies and infrastructure (Plazzotta and Manzocco, 2019). Managing risks like toxins and ensuring consumer acceptance require further research. Industrial integration, including reintegration into original products or via waste valorization companies, shows promise for maximizing its potential (Isah and Ozbay, 2020).

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PHYSIOLOGY OF CUTTINGS

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Abstract

When propagating plants, that is, multiplying or increasing the number of plants, different methods whether sexual (seeds) or asexual (cuttings, layering, grafting) methods can be used. Different methods have different advantages and disadvantages and are used based on different factors such as the nature or physiology of the plant, availability of growing material, creating hybrids or conserving the desirable features of the mother plants, etc. Use of cuttings is an asexual or vegetative method of propagation which is simple and inexpensive, and creates plants that are true to type to the mother plant. To make sure to successfully propagate by the use of cutting, we need to learn about its physiology and the different factors that affect the rooting of the cuttings.

Introduction

In propagation by the use of cuttings, a part of the plant such as stem, leaf, root, etc. is cut or detached and used for generation of new plants, which are genetically identical to the mother plant. Cuttings allow us to effectively create clones of a plant with desired traits without undesirable variations. The cuttings are detached from the parent plant and the correct rooting media is used with proper drainage and aeration, as well as nutrients for the proper growth of the cutting. Rooting hormones such as IBA and NAA are applied at the base of the cuttings to encourage root development and optimal conditions are provided for proper development. Once the cutting has properly rooted, it can be transplanted if necessary. For the success of cuttings, it is necessary to learn about its physiology and the various processes that are involved in the rooting of cuttings.

Physiological processes

- 1) Wound response : Wounding triggers a response for the protection and survival of the plant. It initiates the healing process and mechanisms such formation of callose layer as well as changes in hormone levels. Levels of hormones such as auxin are increased at the site of the wound which stimulate the initiation and development of roots. In this way, the wounds stimulate the rooting of the cutting as a means of protecting the plant.
- 2) Energy source : Formation of new roots require energy. Depending on the type of cutting, the energy may be provided by different sources. In case of softwood stem cuttings which are young, soft, and succulent with leaves left on the cutting, the energy is provided by the photosynthesis performed by the leaves. In case of hardwood cuttings which are taken from mature, dormant stems, the energy is provided by the stored reserves in stem itself, not relying on photosynthesis.
- 3) Root formation : The increased concentration of auxin, particularly Indol-3-acetic acid, helps in the formation of adventitious roots. This increased concentration is brought by the wound response in the cutting. The auxin promotes the cell division in the basal region of the cutting with the wound, which helps in root formation. To further promote root formation, the cuttings may be treated with rooting hormones like auxins such as Indol-3-butyric acid (IBA).

- 4) **Water uptake** : The newly formed plant needs to absorb water from the soil to survive. As the roots are formed, a proper vascular system consisting of xylem and phloem is established for nutrient and water distribution within the plant. The newly formed roots absorb water by the process of osmosis, moving it from high concentration outside to the low concentration inside. The suction created by transpiration pulls water upward through xylem. The absorbed water reaches the leaves where it is used for photosynthesis.
- 5) **Nutrient uptake** : The plant also needs to absorb the required 17 essential nutrients like carbon, nitrogen, potassium, iron, etc. from the soil for building organic molecules to grow and develop. The absorption of nutrients take place via both passive and active processes. The passive process of diffusion moves the nutrients from the soil where they are available in higher concentration into the root cells where they are available in lower concentration. Then energy, in the form of ATP, is utilized to actively move nutrients across cell membrane. The active transport moves the nutrients against the concentration, going from low concentration region to high concentration region.
- 6) **Nutritional factor** : A higher carbon to nitrogen (C:N) ratio has been observed to give better results in rooting. While a low C:N ratio can limit rooting. This ratio reflects the overall nutritional balance of the plant.
- 7) **Environmental factors** : The factors such as temperature, light, and humidity affect the physiology of cuttings. Higher than optimal temperature poses the threat of desiccation while low temperature reduces metabolic activity resulting in slower growth. Extreme sunlight can damage the plants while low levels hinder the photosynthesis process. Excessive humidity may pose the threat of root rot or diseases while not having enough humidity may result in wilting. Having optimal environmental conditions is necessary for proper physiological development of cuttings.

Conclusion

The physiology of cuttings involves a complex process with the effect of internal as well as external factors such as hormones, environmental factors, and nutrient availability, as well the condition of the plant part itself that influences its growth into an independent plant. All the factors work together to determine the successful rooting and thus it is necessary to understand these factors for efficient propagation with high success rate.

NANOTECHNOLOGY

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Introduction

As the world confronts rising food demand, shrinking arable land, and climate change, agriculture must evolve. One of the most promising innovations is nanotechnology—the manipulation of materials at scales of 1–100 nanometers. These nano-scale interventions are improving nutrient delivery, pest control, water management, crop monitoring, and post-harvest preservation. This article explores how nanotechnology enhances agricultural efficiency, the challenges it faces, and its future potential.

Why Nano? Small Scale, Big Impact

At the nanoscale, materials gain unique properties:

- Gigantic surface-area to volume ratios, boosting reactivity, solubility, and absorption.
- Precise tuning of release and targeting through coatings and encapsulation.
- Cell-penetration capabilities, enabling direct delivery into plants. These traits enable nanotech tools to outperform conventional methods by improving uptake, reducing waste, and minimizing environmental harm.

Smart Nutrient Delivery with Nanofertilizers

1. Efficiency & Environmental Benefits

- Slow, controlled nutrient release minimizes leaching and volatilization—unlike conventional urea, where 50–90% of nitrogen is lost. Enhanced plant uptake: some phosphorus nanofertilizers reach up to 90.6% absorption, compared to <30% usual. Water and cost savings: using less fertilizer reduces expenses and runoff pollution.

2. Real-World Examples

- Nano-urea in India: a 500 ml nano-urea bottle equals one 45 kg bag of traditional urea, while halving usage. It costs less (₹240 vs ₹267) and boosts yield by ~8%, reducing soil and water contamination.
- Iron-oxide nano-priming enhances wheat seed germination, root strength, and grain nutrient content. Key Takeaway: Smart nutrient delivery through nanofertilizers boosts uptake, reduces application rates, saves water, curbs pollution, and helps crops thrive.

Precision Pest & Disease Control with Nanopesticides

1. Targeted Action, Less Pollution

- Nanopesticides bind particles to plant surfaces, use controlled release, and can be pH-activated by pests—reducing total chemical use.

- Nano-herbicides (e.g., atrazine in polycaprolactone) and copper nanopesticides combat weeds and fungal diseases with less environmental toxicity.

2. Enhanced Disease Management

- Nano-encapsulation protects active ingredients, enabling prolonged release and fewer applications.
- Nanobarcode tools help quickly detect pathogens, allowing faster, targeted interventions.

Real-Time Crop Monitoring via Nanosensors

1. What They Do

- Monitor soil moisture, nutrient levels, pH, temperature, and early signs of disease or pests.

2. How Farmers Benefit

- Scan irrigation needs, cutting water usage and conserving resources. Spot nutrient or disease issues early, enabling timely, precise action.
- Integrate with precision farming systems, GPS, and AI for data-driven decisions.

Water Management & Soil Remediation

1. Nanoscale Water Solutions

- Nanomembranes and carbon nanotube filters purify irrigation water by removing salts, heavy metals, pathogens.
- Nanomulches, like superhydrophobic sand, reduce evaporation by up to 73%, raising yields in arid regions.

2. Soil Cleanup

- Nano-clays, carbon nanotubes, and zero-valent iron nanoparticles bind to heavy metals and pesticide residues, aiding in soil detoxification.

Post-Harvest Shelf Life & Food Safety

- Nanopackaging extends shelf life via antimicrobial surfaces, moisture and gas control—reducing food waste..
- Nanosensors in packaging detect spoilage or contamination for quality assurance.

Health, Environmental & Regulatory Considerations

1. Safety Concerns

- Some nanoparticles (e.g., copper, silver, TiO₂) might disrupt soil microbiology or harm non-target organisms, depending on dose and form.
- Long-term environmental persistence and human exposure risks require robust evaluation.

2. Governance Gaps

- Regulatory systems for nano-agrochemicals are still evolving. Clear guidelines and labeling are needed.

The Road Ahead

1. Innovation & Scalability

- Costs of nano-materials are falling; India's nano-urea example shows local manufacturing scalability.
- Future tools include nanocarriers for gene editing and biodegradable nano-mulches with energy-harvesting sensor layers.

2. Adoption & Integration

- Success requires integrating nano solutions into precision-ag systems alongside education, extension support, and community trust-building.
- Longitudinal environmental studies and clearer labeling are key to building confidence.

Conclusion

Area	Advantage
Fertilizers	Higher uptake, less waste, lower cost
Pesticides	Precise action with fewer chemicals
Monitoring	Real-time data for optimal resource use
Water & Soil	Purification, reduced evaporation, soil cleanup
Post-Harvest	Extended shelf life, improved safety

Nanotechnology is redefining farming efficiency across multiple fronts:

The pathway to sustainable, global-scale adoption depends on safety research, clear regulation, farmer training, and cost-effective production. But with technology accelerating, nano-enabled farming could be a cornerstone of future food security.

Further Reading & Resources

- In-depth reviews on nano-biosensors, seed nano-priming, and soil remediation
- Case studies like India's nano-urea deployment
- Overviews of environmental chemistry and safety of nanomaterials .

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PERSPECTIVES AND SHORTCOMINGS CONCERNING MICROPLASTICS IN AQUATIC ENVIRONMENT

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Abstract

The occurrence of microplastics in the aquatic environment has become a growing concern globally. Microplastics pose a hazard to the ecological system, and their presence, particularly in the water, has an adverse impact on human health and the ecosystem. Microplastics are released into the environment directly from everyday used plastic items, degradation of plastics, industries, and waste water treatment plants. Once these contaminants enter the water, aquatic life feeds on them, and microplastics enter the food chain and cause severe health hazards. An assessment of microplastics' ecological risks is essential; however, it is challenging in the present scenario due to limited information available. To fill these knowledge gaps, this paper comprehensively reviews the sources and transport of microplastics in the water environment and their environmental and health effects, global policy frameworks, analytical techniques for microplastic detection, and control strategies to prevent microplastic release in the aquatic environment.

Keywords: Microplastics, Aquatic environment, Wastewater treatment plants, Polystyrene microplastics.

Introduction

The European Chemical Agency (ECA) defines microplastics as plastic pieces less than 5 mm in size. Microplastics are often categorized as primary microplastics, which are manufactured for a particular application such as micro-beads, and secondary microplastics, formed by fragmentation and degradation of microplastics, including the fibers from synthetic fibers. A common way for microplastics to enter into the environment is through all the stages in the life cycle of the plastics products (from producers to the waste management systems), which having the potential for trophic transfer and human health exposure. In 2015, a study reported that 6300 million tons of plastic waste was generated, out of which 9% was recycled, 12% was incinerated, and 79% ended in landfills or the environment. The atmosphere is an essential pathway for the transportation of many suspended materials to the surfaces of the water bodies and even the urban, rural, and remote areas by processes such as the wind speed and the direction, up/down drafts, convection lifts, and turbulence. Earlier studies have found pieces of plastics raining from the sky at an average daily rate of 365 microplastic particles per square meter. In 2017, an analysis of global tap water samples found 83% of the collected samples contaminated with microplastics. The researchers have analyzed samples from the storm and sea fog and reported that the microplastics in sea spray ranges between 5 μm and 140 μm .

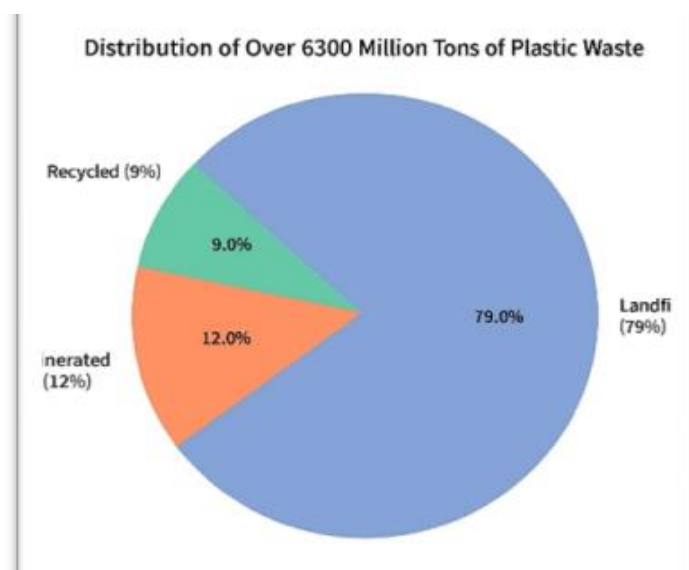


Fig.1. A pie diagram showing the fate of plastic waste generated

Source and transport of microplastics

Microplastics are present in every part of the environment. The primary sources of microplastics include household discharge, such as polymeric plastic from cosmetics and cleaning products, feedstocks used to manufacture these products, and the plastic powder or pellets used for air blasting, accounting for almost 5000–80,000 tones. Human activities have a huge impact and contribution to the aquatic environment. A study reported that from 4.8 to 12.7 million metric tons of untreated plastic waste enters the oceans from coastal countries annually. The transport of plastic debris in the aquatic environment has gained much attention. The process of microplastics entering the water bodies depends on the characteristics of the microplastics. The physical and chemical properties of the water bodies, such as hydrodynamics, attachment, and uptake of the aquatic environment, also affect the settlement, re-suspension, and transportation distance of the plastic particles, ultimately contributing negatively to the environment. Microplastics' concentration in the environment varies from 10 to 1000 μm . The omnipresence of plastic contamination can no longer be rejected.

Different Sizes of Microplastics

Microplastics are generally defined as plastic particles smaller than 5 millimetres (mm) in size, but they can vary widely in their dimensions, which affects their environmental behavior, transport, and biological impact. Based on size, microplastics can be broadly categorized into large microplastics (1 mm to 5 mm), small microplastics (1 μm to 1 mm), and nanoplastics, which are particles smaller than 1 micrometre (μm). Larger microplastics are often visible to the naked eye and include fragments, pellets, and fibers from broken-down plastic items. These are more likely to be filtered out during wastewater treatment processes. Smaller microplastics, including those from cosmetic products and synthetic textile fibers, are harder to detect and may escape conventional filtration systems. Nanoplastics, the smallest category, pose the greatest environmental and health risks due to their ability to penetrate biological membranes, accumulate in tissues, and interact with cellular functions. The smaller the particle size, the greater the potential for bioavailability and long-term ecological impact. Understanding these size differences is critical for monitoring, detection, and designing effective strategies to mitigate microplastic pollution.



Fig.2. Classification of plastic

Occurrence and Fate of Microplastics

According to a 2017 IUCN report, microplastics contribute to 30% of the Great Pacific Garbage Patch, further polluting the world's oceans. In many developed countries, these are the largest marine plastics pollution source than the visible larger pieces of marine litter. Waste Water Treatment Plants are the major source of microplastics release in the water environment. The sewage systems transport the microplastics into the wastewater treatment systems, effectively preventing the plastic debris from entering the aquatic environments. China alone releases around 9.1×10^{10} microplastics through domestic wastewater every day. About 87%–99% of plastic debris is retained from the sewage at different treatment stages (preliminary, primary, secondary, and tertiary) of WWTP. Plastic debris present in sewage is removed or retained at various stages of wastewater treatment, depending on the size, density, and type of plastic particles.

- 1) In the preliminary treatment stage, large plastic items such as bags, wrappers, and synthetic fibers are captured by screens and grit chambers, which physically filter out coarse materials.
- 2) During the primary treatment, sedimentation tanks allow suspended solids and some heavier plastic particles to settle as sludge, although many microplastics remain in the water column due to their buoyant nature.
- 3) In the secondary treatment, which involves biological processes using activated sludge or biofilm systems, some microplastics may be trapped within microbial flocs and removed during sludge settling. However, lighter microplastics and fibers can still escape this stage.
- 4) The tertiary or advanced treatment stage uses filtration methods such as sand filters, membrane filtration (e.g., ultrafiltration or reverse osmosis), or advanced oxidation processes to further reduce microplastic content in the effluent. Despite these mechanisms, complete removal is challenging, and improving filtration technologies and incorporating microplastic-targeted treatments are increasingly important for preventing plastic pollution in receiving water bodies.

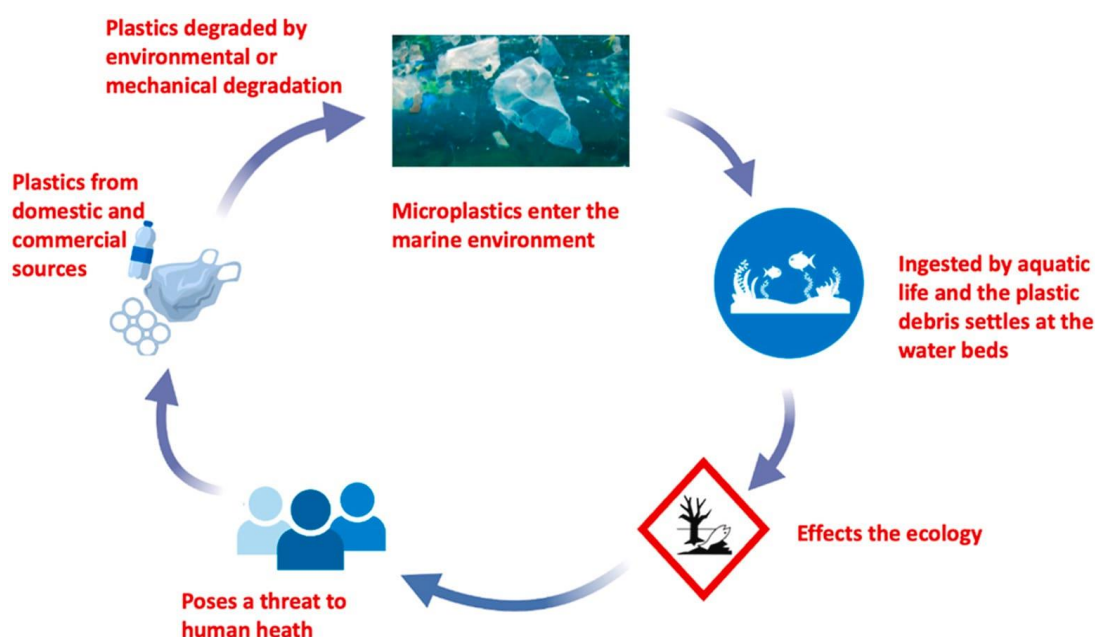


Fig.3. The microplastic circulation

Adverse Health Effects

Several studies have highlighted the toxic effect of microplastics on the environment and human health. A research study established the toxic effect of polystyrene microplastics (PSMPs) on earthworms (*Eisenia fetida*). The study revealed that PSMPs could induce oxidative stress, histopathological changes, and significant DNA damage in the *Eisenia fetida*. The exposure to 1300 nm PSMPs caused substantial toxicity due to its higher bioaccumulation than 100 nm PSMPs. Similarly, the overall toxic effects broadly vary from the interference in the nutrient productivity and cycling in the environment to building physiological stress, including behavioural alterations, immune responses, abnormal metabolism, and changes in energy budgets in several organisms resulting in a threat to the ecosystem composition and stability. Human health effects due to microplastic exposure may lead to particle toxicity, oxidative stress, inflammatory lesions, and increased uptake or translocation. Additionally, secondary infection due to the release of microplastic associated adsorbed contaminants and microorganism, chronic inflammation, and increased risk of neoplasia may further worsen human health.

Challenges for Micro-Plastics Analysis and Treatment

1. Analytical Challenges in Detection & Quantification

- **Lack of Standardized Methods:** There is no globally accepted protocol for sampling, extracting, or analyzing microplastics.
- **Detection of Nanoplastics:** Most techniques (e.g., FTIR, Raman) are limited to microplastics (>1 μm). Detecting nanoplastics (<1 μm) is even more difficult.
- **Contamination Risk:** Microplastic contamination during sampling or lab analysis is common, especially from synthetic clothing or tools.
- **Heterogeneity in Shape & Polymer Type:** Microplastics vary in size, shape (fibers, fragments, films), and chemical composition, making analysis complex.
- **Low Concentrations in Some Environments:** Detecting small quantities in air, drinking water, or human tissue requires ultra-sensitive methods.

2. Treatment & Removal Challenges

- **Limited Removal by Conventional Treatment Plants:** Wastewater Treatment Plants (WWTPs) can only partially remove microplastics. Microplastics often pass through filters or get concentrated in sludge, which may be reused as fertilizer.
- **Fragmentation into Smaller Particles:** Some treatment processes (e.g., oxidation, UV, mechanical stress) may break plastics into nanoplastics, increasing environmental risk.
- **No Specific Technology:** There's no dedicated treatment method yet that can effectively and economically remove all micro- and nanoplastics.
- **High Costs of Advanced Treatment:** Technologies like membrane filtration or advanced oxidation processes are effective but expensive and energy-intensive.

3. Regulatory & Policy Gaps

- **Lack of Regulatory Framework:** Many countries have no specific laws or limits for microplastic emissions in water, air, or food.
- **No Monitoring Obligations:** Governments mandate microplastic monitoring in industrial effluents, tap water, or agricultural soils.
- **Absence of Risk Assessment Protocols:** Limited data on toxicological effects makes it hard to assess and regulate health risks.

4. Environmental and Health Impact Uncertainties

- **Unknown Long-Term Effects:** Microplastics may carry harmful additives or absorb pollutants, but their long-term effects on humans and ecosystems remain poorly understood.
- **Bioaccumulation and Food Chain Transfer:** They can accumulate in aquatic organisms and enter the human food chain, raising health concerns.

Elimination of microplastics from the environment is more challenging than eliminating large plastic debris. Microplastics are ubiquitous and slow degrading contaminants with properties such as long residence time, high stability, high potential of being fragmented, and the ability to absorb other contaminants. Previous studies have also reported the presence of organic pollutants such as polyamide, polyester, polymerizing vinyl chloride, and acrylics in microplastics. Therefore, it is necessary to investigate and develop methods to eliminate microplastics from the aquatic environment. This review focuses on the properties of microplastics, their toxicity, and their health effects. The source, transport occurrence, and detection and removal methods with their advantages and disadvantages are also discussed in detail.

Control and Management Strategies

Effective control and management of microplastics in the aquatic environment require a multi-tiered approach involving prevention, policy enforcement, technological advancement, and public participation. The most crucial strategy is source reduction, which includes minimizing the production and use of single-use plastics and replacing them with biodegradable or sustainable alternatives. Strengthening waste management systems, such as improving recycling processes, ensuring proper segregation of plastic waste, and upgrading wastewater treatment plants to filter microplastics, can significantly reduce their entry into water bodies. Legislative measures, such as banning microbeads in cosmetics, implementing extended producer responsibility (EPR), and enforcing plastic waste management rules, are essential at national and international levels. Technological innovations like microplastic filtration systems in washing machines and advanced

treatment technologies in sewage plants can aid in capturing smaller plastic particles. Additionally, public awareness and education campaigns are vital to changing consumer behavior and promoting responsible plastic use and disposal. Lastly, continuous scientific research is necessary to understand microplastic behavior, impacts, and removal methods, which can inform evidence-based policy and management decisions.

Conclusion

Plastic polymers are inseparable items from people's lives as plastics' demand increases in direct and indirect applications. The plastic is released into the environment whenever plastic is used, which breaks into smaller debris (microplastics) due to environmental factors, and transport to water bodies. Hence it is essential to establish models with the help of data and practical verification to understand the transport and the risk assessments of microplastics.

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PRESERVING ODISHA'S INDIGENOUS TECHNICAL KNOWLEDGE IN FISHERIES: A PATHWAY TO SUSTAINABLE AQUACULTURE

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Abstract

Odisha's Indigenous Technical Knowledge (ITK) in fisheries represents a vital reservoir of sustainable and eco-friendly aquaculture practices. Rooted in traditional wisdom and local experience, these techniques encompass pond preparation, seed selection, integrated fish farming, seasonal fishing patterns, and organic fish preservation methods. Despite their relevance to sustainable development, these practices are increasingly at risk due to modernization, migration, and lack of documentation. This article explores key examples of ITK in Odisha, such as the use of natural inputs, bamboo fishing gears, and community-led seasonal calendars for fish breeding. It highlights the importance of integrating ITK into mainstream fisheries development, research, and policy frameworks. By validating and preserving these traditional practices, Odisha can pave the way for a resilient, inclusive, and environmentally sound aquaculture system. The study calls for urgent action in documentation, education, and policy support to ensure that this invaluable knowledge is not lost but adapted and sustained for future generations.

Introduction

Indigenous Technical Knowledge (ITKs) can be defined as the expertise, skills, practices, ideas, experiences, and information accumulated over an extended period, which is maintained and transmitted orally from one generation to the next within a community situated in a specific geographic region, often becoming an integral part of its culture. This knowledge also encompasses the know-how, experiences, and practices that are developed, utilized, and preserved by individuals who have a close relationship with their natural surroundings. An ITK is characterized by being socially desirable, economically viable, sustainable, involving minimal risk, and emphasizing the efficient use of environmentally friendly resources (Ponnusamy *et al.*, 2009; Shenoy, 2009). Indigenous knowledge can be local or derived from other regions (Van Der Bleik and Van Veldhuisen, 1993), having been developed and transformed through informal research conducted by a community in a specific area and integrated into their lifestyle. Numerous research studies have indicated that the application of traditional knowledge by farmers is more prevalent in areas that are complex, diverse, and prone to risk. In Odisha, a coastal state of India, ITKs play a crucial role in fisheries management and the sustainable utilization of aquatic resources. These practices are characterized by their low cost, eco-friendliness, and adaptability to local conditions. With Odisha's

diverse geography encompassing extensive coastlines, estuaries, rivers, and Asia's largest brackish water lagoon—Chilika Lake—traditional knowledge has evolved to meet local ecological and livelihood needs.

Fisherfolk Knowledge: A Natural Asset

Communities like the Nolias and tribal groups such as the Kondhs and Sauras have long relied on time-tested fishing techniques. Traditional gear such as 'Dhadi jal' (bamboo trap), 'Ber jal' (stationary net), and the ingenious 'Katha' fishing method in Chilika Lake represent efficient, eco-friendly alternatives to mechanized practices. These tools, crafted from bamboo, jute, and coir, have minimal environmental impact and support biodiversity.

Reading the Tides and Moon

Odisha's fishers follow lunar cycles and monsoon patterns to plan fishing activity. Peak breeding periods, identified using traditional knowledge, are respected with voluntary no-fishing days, a natural form of resource conservation. Such calendar-based approaches ensure stock regeneration and long-term sustainability.

Preserving the Catch, Naturally

Sun-drying, smoking over paddy husk, and salt-curing are widely used preservation techniques, particularly in coastal districts like Ganjam and Kendrapara. These methods are still prevalent in 'Sukhua bazaars' (dried fish markets), offering high shelf-life and economic value without refrigeration.

Natural Hatcheries and Traditional Aquaculture

Fishers identify natural spawning zones and collect wild spawn of Indian Major Carps, nurturing them in backyard ponds with rice bran and mustard cake as feed. These time-honoured practices are foundational to India's inland aquaculture story and present low-input models worth preserving.

Community-Driven Governance

Local village councils have traditionally managed common water bodies through rotational rights and seasonal bans. Fisheries disputes are resolved collectively, and knowledge is passed through oral traditions. This social capital can serve as a model for inclusive co-management frameworks promoted by ICAR and FAO.

Modernization Threatens Heritage

The increasing focus on mechanization, declining youth interest, and lack of formal recognition are threatening ITKs. According to a 2022 Odisha Fisheries Department report, only 25% of youth in traditional fishing families are aware of their ancestral methods. Without documentation and incentives, this wisdom may vanish.

Why ITK Still Matters

ITKs are climate-smart, cost-effective, and ecosystem-based. In a world where sustainable aquaculture is the need of the hour, Odisha's indigenous practices offer valuable lessons in low-carbon development and community-led resilience. Integrating these practices with scientific training can reduce input costs and restore environmental harmony.

Conclusion

Odisha's Indigenous Technical Knowledge is not a relic of the past, but a roadmap for a sustainable future. Policymakers, extension officers, and researchers must collaborate to document, validate,

and promote these practices. It is time we value the fishers not just for their catch, but for their knowledge.

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AGROTOURISM

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Agritourism: Converting wasteland into useful land

New identity of rural India : - To link the beauty of the village with employment, agricultural tourism has been started , through this avenues of employment are opening up for farmers and village people .

Introduction of agricultural tourism-

Shri Pandurang Taware : Considered as the “Father of Agritourism” in India, Shri Pandurang Taware introduced the concept of linking tourism with agriculture.

World Tourism Day is celebrated every year on **27 September** to promote the importance of tourism and highlight its social , economic and cultural contributions.

And to promote tourism in India and increase awareness among people, **National Tourism Day** is celebrated on 25 January. It is celebrated



Agricultural Tourism (File Photo) Shri Ram College Muzaffarnagar

Role of agricultural tourism for rural development : Mahatma Gandhi has rightly said that the village is the soul of our country. The soil there has a sweet fragrance , which gives peace to the mind. Even though the life of the village is simple , there is a sense of belonging , peace and a deep connection with nature. The sound of chirping birds in the morning , the lush green plants waving in the fields , and the clean air - all these together make the village like a paradise. This is the reason why people take a small break from the hectic life of the cities and head towards the village in search of peace.

The villages of India present an example of culture and environmental conservation to the whole world , where farming is done while preserving natural resources. To link this beauty of the village with employment, agricultural tourism has been started , through which avenues of employment open up for farmers and village people.



What is Agricultural Tourism ?

Opening the beauty of the village and farming in the lap of the environment for people to see is agro tourism in the true sense . In agricultural tourism , the greenery of the fields, orchards laden with fruits , flower gardens spread on the ground soothe the eyes and refresh the mind. For such an experience, tourists spend lakhs of rupees and are ready to go even to far-off foreign countries.

For example, in India, the agro-tourism places of Goa , tea gardens of Kerala , hills of the Northeast and valleys full of fruits and flowers of Kashmir attract tourists from the country and abroad. In such a situation, if a tourist farm is established by the farmers, their income will not only increase , but the local villagers will also benefit a lot.



Farm based farming or Agro Farm Tourism (Agriculture Farm Tourism or Farm Based Tourism)

Farmers get many benefits by doing farm based farming. In true sense, the method of farming is inspired by the integrated agriculture system. Where different types of crops are cultivated with the help of agricultural farm. It includes fruits , vegetables , grains , horticulture as well as animal husbandry, fish farming and bee farming .

- By joining agro tourism, farmers become self-reliant and also get a new source of income.
- With its help, farmers also get inspiration for modern farming and to improve the lifestyle of the village and keep it clean.
- Especially by doing organic farming, it becomes easier to sell the organic products grown by the farmers.
- In agro tourism, arrangements for sleeping, boarding and lodging are made in the agricultural farm itself for the tourists.
- In this way, city dwellers not only find peace in villages , but also get acquainted with the culture of the villages by visiting them.

**Things to note (Start Agriculture Tourism This Way)**

- Agro Tourism, the agricultural farm should be developed using completely organic methods, which should include mud houses plastered with village mud , earthen pots and straw as well as thatched roofs.
- This will not only promote organic farming , but along with agro farms, animal husbandry for dairy , poultry farming behind the farm , fish farming in the pond and beekeeping in the fields will also provide food arrangements.
- Use traditional arts to decorate the agro farm, arrange swings under the trees and arrange bullock or horse carts to roam around the village. For example, in Kerala, tourists ride elephants and in Rajasthan, camel rides are a centre of attraction in themselves. People come here to get a touch of nature.

- Through agro tourism, people of the city are able to gain basic knowledge about farming and farmers also get help in marketing the organic products produced from their farms. It becomes easier.

Benefits of Agricultural Tourism

Combines agriculture and tourism , giving visitors a chance to experience farm life while providing economic , educational and environmental benefits. Here are the key benefits:-

Farmers Additional Income : Diversifies income sources beyond traditional farming.

Market Expansion: Provides a direct sales channel for agricultural products (e.g. , farm-to-table experiences, homemade goods).

Employment Generation: Increases employment opportunities in rural areas.

Educational experience for tourists: **Visitors** learn about agriculture , food production and rural lifestyle.

Recreational activities : **This** includes farm stays , fruit picking , wine tasting , animal feeding, etc.



Cultural exchange : Promotes understanding of local traditions and rural heritage.

Economic development for local communities : Promotes local businesses such as restaurants, transportation, and crafts.

Education and Experience for Urban People:

People living in cities see farming and rural life only in books or on TV. Agricultural tourism gives them a chance to see all this in real form.

Conservation of rural areas : encourages the preservation of landscapes and traditional practices.

Improvements to infrastructure : **Better roads** , signage, and utilities are often built in rural areas.

Environmentally Sustainable Practices : Promotes organic farming and eco-friendly methods.

Conservation Awareness : Educates visitors about nature and biodiversity conservation.

Main agro tourism destinations in India

- **Maharashtra**: Agricultural tourism centre of Baramati is contributing a lot in this sector .

- **Kerala:** Tours to organic farms and spice plantations in Wayanad and Munnar are proving popular.
- **Punjab:** Rural homestays and tractor rides are attracting a lot of tourists.
- **Uttarakhand:** Hill farming and folk culture are the main features here.

Agritourism in India is experiencing unprecedented growth , driven by urban interest in rural experiences and government initiatives aimed at rural development and sustainable agriculture. An overview of the current scenario is as follows:

Economic impact on Indian market

Projected Growth - Indian agritourism market is expected to grow at a CAGR of around 17.91% from 2024-2032.

Annual growth rate - As per 2019 data, the sector is growing at a rate of 20% per year, reflecting the growing interest in rural and tourist experiences.

Urban demand : Growing urban population wants to experience farms and nature, agricultural activity and attraction towards traditional cuisine.

Government Help : Swadesh Darshan Scheme And state-level initiatives like Nation in Maharashtra, Sikkim, and Uttar Pradesh promote agricultural tourism through infrastructure development and subsidies.

Sustainable practice : Agritourism is preserved with sustainable development characteristics by supporting rural livelihoods and preserving agricultural traditions.

Maharashtra - As a pioneer, Maharashtra Agri Tourism Development Corporation (ATDC) has established more than 700 agri tourism centres which attract about **8 million tourists** including 50,000 international visitors .

Himachal Pradesh : The state has been promoting agricultural tourism by taking advantage of its diverse agricultural products such as medicinal herbs , saffron and offering educational agricultural tours and foreign tourists also enjoy it.

Conclusion

Agrotourism is not just a way to spend a holiday , but it builds a bridge that connects villages and cities. And this not only strengthens the farmers , but also shows the way of employment to rural youth and tourists are also able to connect deeply with nature and Indian culture. In the coming time, this sector will not only promote tourism , but will also prove to be a strong step towards self-reliant India.

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ARTIFICIAL CULTIVATION TECHNIQUES OF MAITAKE (*Grifola frondosa*) MUSHROOM

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Abstract

Maitake (*Grifola frondosa*) is an edible and medicinal mushroom valued for its flavor and therapeutic properties. Native to temperate forests, it was traditionally collected from the wild but is now cultivated using standardized techniques. This article outlines the morphology, nutritional profile, and artificial cultivation techniques: bottle, bag, and outdoor bed culture, highlighting their comparative benefits and limitations. With rising global interest in functional foods, maitake holds strong prospects for nutritional, medicinal, and commercial value.

Keywords: Maitake, Mushroom, *Grifola frondosa*, Cultivation technique

Grifola frondosa, commonly known as maitake, sheepshead, or hen of the woods, is an edible and medicinal mushroom. It is also known as “HuiShuHua” in China and was historically discovered by an Italian. It is a macrofungus belonging to the phylum Basidiomycota, class Agaricomycetes, order Polyporales, and family Grifolaceae (Cui et al., 2024). It is a saprophytic fungus that naturally grows on fallen logs or at the base of stumps of Fagaceae trees such as *Fagus crenata* (Japanese beech), *Quercus serrata* (Japanese oak), and *Quercus crispula* (Mountain oak). Maitake is popular in Japan, China, Korea, parts of Europe, and North America, where it is used as a food or food additive due to its rich, woody flavor and meaty texture (Gargano et al., 2020; Cui et al., 2024).

Traditionally, it was considered a rare and valuable mushroom, often called the “dancing mushroom”—a name derived from the Japanese words mai (dance) and take (mushroom)—as people who found it in the wild were so thrilled they danced with joy and kept its location secret. Due to its scarcity, it was once sold at high prices (Ulbricht et al., 2009).

However, the artificial cultivation of maitake began in Japan, and mass production commenced soon after researchers gained a clearer understanding of its cultural biology. This has made maitake more readily available in markets and increased its popularity due to its excellent taste and texture. In addition to its culinary uses, scientific studies have shown that purified polysaccharides and extracts from maitake have several health benefits, including antitumor, antidiabetic, antihypertensive, immunomodulatory, antihyperlipidemic, and antiviral activities (Camilleri et al., 2024).

Morphology

Its fruiting body has a wavy appearance with overlapping caps arising from a single, branched stem structure. The caps range in color from grey to brown, while the undersides are white to cream and contain one to three small pores. This mushroom grows naturally in a rosette pattern. The fruiting bodies typically range from 10 to 60 cm wide and 7.5 to 40 cm tall, weighing between 1.3 and 4.5 kg (Cui et al., 2024).

Nutritional Value

The fruiting bodies of *Grifola frondosa* grown on logs and sawdust contain approximately 1.02–1.78% protein, 0.11–0.23% fat, and 6.06–6.90% carbohydrates on a dry weight basis. They also

contain vitamin D2 (ergocalciferol) in the range of 7.84–15.46 IU per gram, along with important minerals such as potassium, phosphorus, sodium, calcium, and magnesium. The highest amount of free amino acid is L-glutamic acid (8.01–9.01 mg/g). Compounds similar to monosodium glutamate (MSG) and sweetness components—present at 9.62–10.35 mg/g and 10.37–11.47 mg/g, respectively—give maitake its distinctive umami flavor (Bae *et al.*, 2024).

Different Artificial Cultivation Techniques of Maitake Mushroom

The artificial cultivation of *Grifola frondosa* (maitake) is carried out using three main methods: **bottle culture**, **bag culture**, and **outdoor bed culture** (Mayuzumi, & Mizuno, 1997), each with its own advantages, limitations, and procedures.

1. Bottle Culture Method

In this method, sawdust powder from deciduous broadleaf trees is mixed with 15% rice bran and 5% wheat bran. The moisture content is adjusted to about 65%. Approximately 400 grams of this substrate is packed into polypropylene bottles (800–1000 ml capacity). The bottles are sealed and steam-sterilized, then cooled to room temperature. Each bottle is inoculated with 15 ml of spore suspension and incubated at 23°C and 70% relative humidity for about 40 days. After colonization, bottles are moved to a fruiting room maintained at 17°C and 85% humidity, with good ventilation. High humidity during fruiting can cause watery mushrooms. While suitable for year-round production and mechanization, this method yields only 100–130 grams per bottle.

2. Bag Culture Method

This is the most common method due to high productivity and commercial suitability. A substrate of sawdust with 15% rice bran and 5% wheat bran (moisture ~65%) is filled (~2.5 kg) into polypropylene bags (12×20 cm base, 35 cm height). A 1.5 cm hole filled with urethane wool is made for aeration. Bags are sterilized, cooled, and inoculated with 30 ml of spore suspension. Incubation is done in dark rooms at 23°C and 70% RH for about 70 days. After colonization, bags are opened and transferred to fruiting rooms with 18°C, 85% RH, and controlled light and airflow. This method can yield about 400 grams per bag and is ideal for commercial setups, though it requires monitoring for contamination.

3. Outdoor Bed Culture Method

This was the first artificial cultivation technique developed in Japan. It is similar to bag culture but uses corn bran and 5% soil instead of rice bran. Silty loam soil with pH 6–7 is preferred. Beds are inoculated in early spring at around 15°C. Incubation conditions are maintained by watering and night heating. After colonization, the bags are removed, beds are covered with a 3 cm soil layer, and placed in shaded fields with 85% black mesh. Fruiting begins in early autumn (23°C). This method is low-cost and produces 1–1.5 kg per bed with excellent wild-like quality, although it requires longer cultivation time and more labour.

Comparison between different cultivation techniques of Maitake Mushroom

Parameter	Bottle Culture	Bag Culture	Outdoor Bed Culture
Substrate Composition	Sawdust + 15% rice bran + 5% wheat bran	Sawdust + 15% rice bran + 5% wheat bran	Sawdust + corn bran + 5% soil
Substrate Quantity	~400 g per bottle	~2.5 kg per bag	Similar to bag, placed in soil beds

Parameter	Bottle Culture	Bag Culture	Outdoor Bed Culture
Container Type	Polypropylene bottles (800–1000 ml)	Polypropylene bags (12×20 cm base, 35 cm height)	Plastic bags (initial) → removed & placed in soil beds
Inoculation	15 ml of spore per bottle	30 ml of spore per bag	Similar to bag culture
Incubation Conditions for mycelial growth	23°C, 70% RH, 40 days	23°C, 70% RH, 70 days	15°C, Controlled via watering/ heating
Fruiting Conditions	17°C, 85% RH, well-ventilated	18°C, 85% RH, light and airflow added	23°C autumn, shaded fields, 85% shading by black mesh sheet
Yield/Unit	100–130 g	~400 g	1–1.5 kg per bed
Production Duration	~2 months	~3 months	~6 months
Cost of Setup	Low–Moderate	Moderate	Low
Labour Requirements	Low (mechanizable)	Moderate	High (manual, soil handling)
Control over Environment	High (indoor control)	High (indoor control)	Low (depends on outdoor conditions)
Taste & Texture	Good, may be watery if humidity too high	Excellent, commercially desirable	Best—resembles wild maitake, firm & flavorful
Suitability	Year-round, mechanized setups	Commercial-scale production	Traditional, low-tech, large space required
Limitations	Lower yield per unit volume	Risk of contamination, requires monitoring	Longer cultivation time, weather dependent

Harvesting

Harvesting maitake mushrooms at the right time and with proper techniques ensures good quality and supports further growth. Mushrooms are typically ready 1–2 weeks after fruiting bodies emerge. The ideal stage is when the caps are fully open, but the edges remain slightly curled. Gently twist and pull the mushroom from the base or use a clean, sharp knife to cut it close to the base. This avoids damage to the mycelium, ensuring continued productivity.

Conclusion

Maitake cultivation, once limited to wild harvesting, has evolved into a controlled practice using bottle, bag, and outdoor bed culture methods. Each technique offers distinct advantages depending on the production scale and environmental conditions. Given its nutritional and medicinal value, maitake has strong potential in the food and pharmaceutical sectors. Promoting local strains, cost-effective techniques, and farmer training programs can support its widespread adoption. Maitake cultivation not only offers commercial promise but also contributes to sustainable livelihood generation, especially in rural and tribal areas.

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AUTOMATION AND AI IN AQUACULTURE – IMPROVES THE YIELD AND REDUCES THE ENVIRONMENTAL IMPACT

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Introduction

Aquaculture, the cultivation of aquatic organisms, is a rapidly growing food production sector that provides protein and supports economic development in coastal and rural communities. However, it faces challenges such as environmental impact, disease outbreaks, resource management, climate change, and economic and operational challenges. Overuse of resources, disease outbreaks, and the use of antibiotics raise concerns about environmental harm and drug resistance. Climate change, rising water temperatures, and unpredictable weather patterns further disrupt aquatic ecosystems. The increasing global demand for seafood and environmental challenges necessitate sustainable aquaculture practices. Automation and AI offer innovative solutions to enhance productivity, reduce environmental impact, and ensure long-term sustainability. These include automated feeding systems, water quality monitoring, early disease detection, resource optimization, labor efficiency, environmental sustainability, and data-driven decision making. AI-driven systems optimize feed distribution, reduce waste, and support eco-friendly practices. These technologies are crucial for transforming aquaculture into a more productive, cost-effective, and environmentally sustainable industry.

Automation in Aquaculture

A) Smart feeding and water quality monitoring:

Smart feeding systems and AI-driven water quality monitoring are crucial for sustainable aquaculture. These technologies use automation and AI to deliver precise feed amounts, optimize feeding schedules, and reduce waste. They also monitor water quality using real-time sensors, AI-based prediction models, and automated aeration and filtration. These systems can improve fish health, reduce operational costs, reduce pollution, and prevent disease outbreaks. By integrating these technologies, aquaculture operations can achieve higher productivity while supporting environmental sustainability. The benefits of these systems include increased growth rates, reduced operational costs, environmental protection, and disease prevention. Some study developed an internet of things (IoT) system to monitor water quality in aquaculture. It used artificial intelligence to create a water quality prediction model using recurrent neural networks (RNNs) with sequential characteristics. Some study optimized hyperparameters using the Taguchi method and compared 5-layer and 7-layer network architectures. The 7-layer GRU model was found more suitable for the application. The system provided accurate data, improving the survival rate of farmed fish and maintaining DOC higher than the standard value (CSSE, 2023, vol.46, no.3).

B) Robotics for maintenance and harvesting

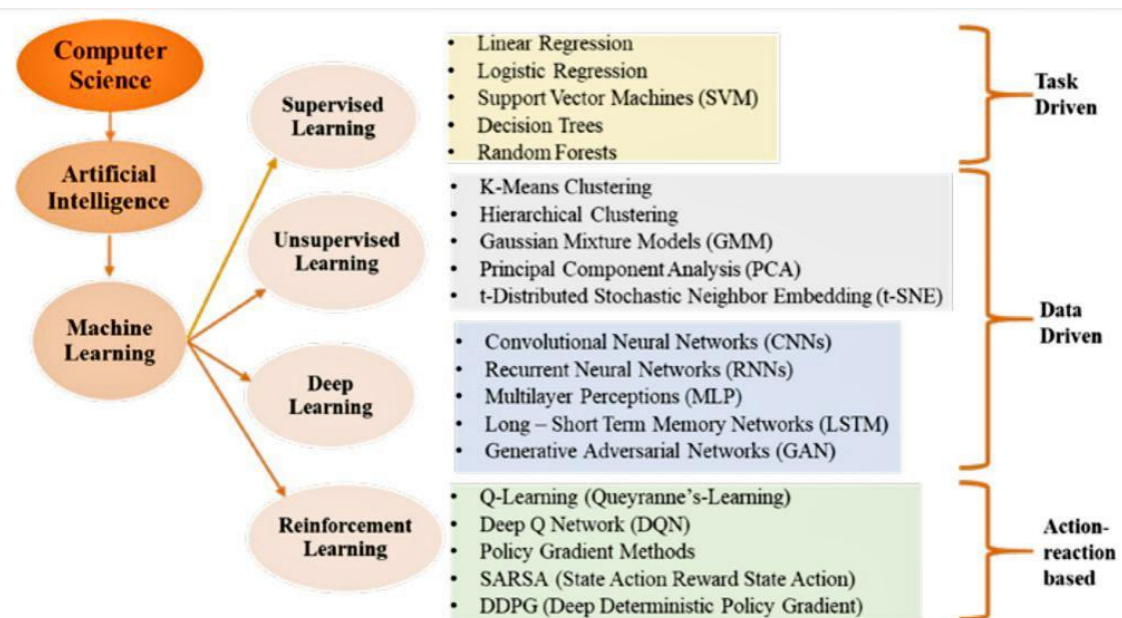
C) Robotics in aquaculture has significantly improved efficiency, reduced manual labor, and promoted sustainable farming. These systems automate routine maintenance tasks and optimize harvesting processes, leading to better yields and reduced operational costs. These systems include

net cleaning robots, underwater drones, waste removal robots, and equipment maintenance robots. Additionally, automated harvesting machines, selective harvesting robots, shellfish harvesters, and sorting and grading systems are being used. The benefits of robotics in aquaculture include labor efficiency, operational cost savings, improved fish welfare, increased productivity, and environmental sustainability. This integration is driving aquaculture towards a more efficient, sustainable, and productive future.

AI Applications in Aquaculture

- In aquaculture systems, feed costs nearly 60% of the total cost invested. Overfeeding can lead to issues such as muscle conversion, cannibalism, and mutual attack. AI plays a crucial role in feeding the right amount of feed at the right time, helping farmers manage their feed intake. Companies like eFishery, Observe Technologies, and Umitron Cell have developed AI feed dispensers that release the right amount of feed at the right time, reducing feed costs by about 21%.
- AI programs can also help prevent diseases by detecting disease outbreaks before they occur by comparing programmed data with collected data from the site. Norway's seafood innovation cluster launched Aquacloud in April 2017, which helped farmers prevent sea lice development in cages, reducing fish mortality and minimizing dependency on expensive treatments.
- Seafood seed screening is another area where AI can help. The Kindai University's Aquaculture Research Institute in Japan uses Microsoft Azure machine learning studio to identify and remove odd-shaped fish seeds from rearing cages. Vision-based sensors on AI devices allow for accurate swimming patterns, size, and injuries on cultured animals, allowing for routine check-ups and quality control.
- AI in shrimp farming involves real-time monitoring of water quality, voice call alerts, appetite-based intelligent feeders, and automatic control of aerators. Indian company Eruvaka provides AI-based solutions for shrimp farmers, including real-time monitoring of water quality, voice call alerts, appetite-based intelligent feeders, and automatic control of aerators.
- AI smartphone applications can assist farmers in testing water quality and predicting diseases. Aquaconnect, an Indian aquaculture technology start-up, created a mobile application called FarmMOJO, which helps shrimp farmers analyze water quality and predict diseases. This helps prevent diseases even before outbreaks start.
- AI in fish processing has increased production by increasing the accuracy of automated robots, leading to increased production. Walmart Inc announced a pilot blockchain technology for end-to-end traceability of shrimp exported from Andhra Pradesh to the United States, aiming to strengthen the shrimp supply chain and enhance food traceability and transparency for consumers in the United States.
- AI in open sea fishing has also been used to reduce overfishing and poaching, especially in areas like the Arctic. Global fishing watch platform collaborated with Google, Oceana, and Sky truth to combine AI and satellite data for understanding fishing activities worldwide. This collaboration allowed for more precise tracking of illegal, unregulated, and unreported (IUU) vessels, poaching, overfishing, and at-sea shipments.
- In conclusion, AI is playing a significant role in aquaculture, improving efficiency, and conservation efforts. By utilizing vision sensors and cameras, AI drones can track endangered

fishes and analyze their habitats faster than humans, making it easier to monitor and conserve aquatic species(Chrispin et al., 2020).



Source : Indian Farming 74 (08): 24-27; August 2024

Environmental Impact Reduction

Aquaculture, a rapidly growing industry, faces environmental challenges such as water pollution, habitat degradation, and resource overuse. Automation and Artificial Intelligence (AI) offer innovative solutions to minimize these impacts and promote sustainable farming practices. AI-driven feeding systems reduce feed waste, energy consumption, and water management, while real-time waste monitoring and automated filtration systems remove excess nutrients and waste. AI models predict disease outbreaks, reduce chemical and antibiotic use, and apply eco-friendly pest control. Natural water treatments are monitored and adjusted using biofilters and probiotics. AI also helps in habitat and biodiversity protection, identifying suitable farming locations and maintaining eco-friendly infrastructure. AI also optimizes stocking densities to prevent overcrowding and habitat damage. Automation reduces fuel and energy consumption, lowering greenhouse gas emissions. Renewable energy integration is managed by AI systems. Circular and sustainable practices include integrated multi-trophic aquaculture (IMTA) and aquaponics integration, which combine fish farming with plant cultivation to recycle nutrients. By integrating automation and AI, aquaculture can significantly reduce its environmental footprint, ensuring long-term sustainability and protecting aquatic ecosystems.

Challenges and Future Prospects

Automation and artificial intelligence (AI) are revolutionizing aquaculture, but they present challenges. High initial investment, technical complexity, data management, limited infrastructure in remote areas, environmental adaptability, and regulatory and ethical concerns are some of the challenges. However, advancements in affordable sensors and AI tools can make automation accessible to small-scale farmers. Open-source AI platforms can reduce software costs, and integration with renewable energy can optimize energy usage for sustainable operations. AI models can improve disease prediction and prevention, enabling targeted treatments. Fully automated

aquafarms using robotics, IoT, and AI minimize human intervention. Blockchain integration with AI ensures traceability and sustainability in supply chains. AI supports circular farming systems and waste-to-resource models, reducing pollution and maximizing resource use. Global collaboration and policy development will drive innovation and standardize AI applications. By addressing current challenges and embracing future innovations, automation and AI can transform aquaculture into a more efficient, profitable, and environmentally sustainable industry.

Conclusion

Automation and Artificial Intelligence (AI) are revolutionizing the aquaculture sector by tackling significant issues concerning productivity, resource allocation, and ecological sustainability. Intelligent feeding systems, monitoring of water quality, and robotic innovations have markedly enhanced operational efficacy, curbed waste generation, and diminished the sector's ecological footprint. Despite obstacles such as considerable initial investments, technical challenges, and regulatory deficiencies, ongoing developments in affordable intelligent technologies and sustainable methodologies present promising avenues for progress. The incorporation of renewable energy sources, progressive disease management strategies, and fully autonomous mechanisms will further bolster the resilience and sustainability of aquaculture practices. Through the implementation of automation and AI-oriented solutions, the aquaculture industry can realize enhanced productivity, reduced environmental impact, and play a vital role in global food security, thereby maintaining an equitable balance between economic advancement and ecological integrity.

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CARBON FARMING: CULTIVATING CLIMATE SOLUTIONS FROM THE GROUND UP

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Introduction

As the planet grapples with rising temperatures, intensifying weather extremes, and escalating environmental pressures, agriculture emerges as a paradox—both a victim of and a contributor to climate change. Yet within this paradox lies possibility. What if agriculture could not only reduce its carbon footprint but actively help cool the Earth?

Carbon farming represents a transformative vision for agriculture. It reimagines farms as part of the climate solution—turning fields into carbon sinks that draw down greenhouse gases, while at the same time rejuvenating soils, enhancing biodiversity, and improving agricultural resilience and productivity.

Reframing Agriculture's Role in the Climate Crisis

Traditionally, agriculture has been framed as a major source of greenhouse gas emissions—through deforestation, methane release from livestock, and nitrous oxide from fertilizers. However, the same landscapes contributing to climate change can also be engineered to mitigate it. With the right techniques, farms can store carbon in the soil and vegetation, transforming themselves into engines of ecological restoration. Carbon farming is not just about sequestering carbon. It's about redefining the relationship between people, land, and climate—about farming not only for yield, but for regeneration.

Carbon farming encompasses a suite of regenerative agricultural practices aimed at increasing the amount of organic carbon stored in soils and plant biomass. By enhancing natural processes like photosynthesis and reducing disturbances to the soil, carbon farming taps into the Earth's own carbon cycle to restore ecological balance.

Techniques such as agroforestry, cover cropping, and hedgerow planting not only sequester carbon, but also support wildlife, improve soil structure, and build resilience to climate shocks. A farm rich in biodiversity is more resistant to pests, diseases, and drought—turning diversity into a shield against climate volatility.

The Carbon Cycle: Nature's Own Balancing Act

Carbon flows continuously among the atmosphere, oceans, soil, and living organisms in a process known as the 'carbon cycle'. But industrialization and deforestation have disrupted this natural equilibrium, resulting in an overaccumulation of carbon dioxide in the atmosphere.

Carbon farming works to restore this balance by increasing the carbon storage capacity of soils through biologically driven techniques. Healthy soils rich in organic matter act as powerful carbon reservoirs.

Sowing the Seeds of Regeneration

Each seed planted on a regenerative farm is a commitment to a better future. Carbon-smart farming involves innovative methods such as:

- Rotational grazing, which mimics natural herd movement to stimulate plant growth and soil health.
- Biochar application, locking carbon in a stable form that can persist in soil for centuries.
- Composting, which enhances microbial activity and builds soil organic matter.

These methods restore degraded soils and sequester carbon, turning farmers into climate stewards. The movement begins with awareness, deepens with education, and flourishes through policy support and global collaboration.



Key Carbon Farming Practices

1. Cover Cropping: Planting grasses or legumes during the off-season keeps the soil covered, prevents erosion, and boosts soil organic matter.
2. Agroforestry: Integrating trees with crops or livestock systems increases biomass, stores carbon, and diversifies farm income through fruits, nuts, or timber.
3. No-Till or Low-Till Farming: Reducing tillage minimizes carbon loss from the soil and lowers fuel use, maintaining soil structure and microbial life.
4. Compost and Organic Amendments: Organic materials enhance soil fertility and stimulate microbial communities that support carbon retention.
5. Biochar: Produced by heating biomass in low-oxygen conditions, biochar captures carbon and enriches soil fertility.

How Soil Stores Carbon

Through photosynthesis, plants convert atmospheric CO₂ into sugars. A portion of these carbon-rich compounds travels to the roots, feeding soil microorganisms. In return, these microbes assist in forming stable organic matter effectively storing carbon underground for years or even decades.

Regenerative Agriculture: A Philosophy of Renewal

Regenerative agriculture is more than a farming method—it's a holistic approach to land stewardship. Unlike conventional systems that often degrade natural resources, regenerative farming aims to heal ecosystems. Techniques like crop rotation, no-till, and integrated livestock management work together to restore soil health, build resilience, and enhance biodiversity. By actively drawing carbon from the atmosphere into the soil, regenerative agriculture becomes a cornerstone of climate mitigation.

Farming for a Cooler Planet

While urbanization and industry dominate the climate discourse, agriculture has untapped potential as a cooling force. Practices like wetland restoration, organic mulching, and tree planting can reduce land surface temperatures, foster evapotranspiration, and lower atmospheric greenhouse gas levels. When managed wisely, farmland can serve as a climate shield. This is the essence of climate-smart stewardship cultivating productivity while regenerating the planet.

Benefits of Carbon Farming

- Captures atmospheric carbon dioxide
- Improves soil fertility and water retention
- Enhances biodiversity and ecological resilience
- Reduces reliance on synthetic fertilizers and pesticides
- Opens income opportunities via carbon credit markets
- Strengthens community engagement and rural livelihoods

Challenges to Adoption

- Despite its promise, carbon farming faces hurdles:
- Limited awareness and technical knowledge among farmers
- Inadequate systems for measuring and verifying soil carbon
- High upfront labor and input costs
- Policy and financial gaps in accessing carbon markets

Addressing these barriers requires coordinated efforts—education, incentives, and infrastructure to support carbon-based agriculture.

A Path Forward: Revolutionizing Agriculture

To reverse climate change, we must revolutionize the way we grow food. This transformation involves shifting from extractive practices to regenerative ones, empowering farmers with tools like AI-powered monitoring, satellite imaging, and precision agriculture. Carbon credit systems can incentivize farmers to adopt sustainable techniques while promoting accountability and innovation. The path to a sustainable food system begins with the soil. When we invest in its health, we invest in the health of the planet.

Growing Hope from the Ground Up

Carbon farming is more than a solution, it's a 'movement', bridging traditional wisdom with modern science. With the right support, farmers can lead the way in reversing climate change, not only feeding the world but helping to heal it. As global awareness grows and policies evolve, carbon farming stands as a powerful testament to what's possible when we work with nature instead of against it. The soil beneath our feet holds the power to cool the sky above.

In its richness lies our resilience, and in its renewal lies our hope.

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CLIMATE CHANGE: ECONOMIC BURDEN ON SMALLHOLDER FARMERS

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Introduction

Climate change has emerged as one of the most critical challenges affecting global agriculture. Smallholder farmers, who constitute over 80% of the farming population in developing countries, are disproportionately vulnerable. These farmers typically operate on less than 2 hectares of land, often without irrigation, insurance, or institutional support. Climate change exacerbates their economic struggles by increasing weather variability, reducing crop yields, and intensifying risks to livelihoods.

Who are Smallholder Farmers?

Smallholder farmers are those managing small plots of land, relying largely on family labor and limited financial resources. According to the **FAO (2017)**, smallholders contribute up to 70% of global food production, yet they remain marginalized in terms of credit, technology, and insurance access.

Key Features:

- Landholding: <2 hectares
- Income Source: Mostly agriculture-based
- Region: Predominantly Sub-Saharan Africa, South Asia, Latin America

Climate Change and Agriculture: A Risky Relationship

Climate change disrupts agriculture through:

- Unpredictable rainfall patterns
- Extended droughts or floods
- Increased frequency of extreme weather events
- Soil degradation and salinization
- Pest and disease outbreaks

These disruptions particularly hurt smallholder farmers who lack adaptive capacity.

According to *World Bank (2020)*, crop productivity could fall by 20–30% in developing regions by 2050 without adaptation.

Economic Burden on Smallholder Farmers

1. Decline in Crop Yields

Climate variability reduces output of staple crops like rice, wheat, and maize.

Example: A study in eastern India showed a 15–20% decline in rice yield due to delayed monsoons (Jha *et al.*, 2020).

2. Increased Input Costs

Droughts or floods require more fertilizer, irrigation, or replanting, increasing production costs.

3. Loss of Income and Food Security

With fewer crops to sell and consume, smallholders suffer from declining incomes and hunger.

Data Point: Nearly 60% of smallholder households in Sub-Saharan Africa faced income loss due to climate shocks in 2022 (FAO, 2023).

4. Damage to Livestock and Fisheries

Heat stress and water scarcity impact dairy animals, poultry, and fisheries – alternative income sources for many smallholders.

5. Infrastructure and Asset Loss

Floods and cyclones destroy infrastructure such as granaries, irrigation lines, and tools—assets that smallholders cannot easily replace.

Gendered Impacts of Climate Change

Women smallholders face compounded risks due to unequal access to land, credit, and information.

- Women often manage less fertile plots and lack irrigation access.
- Societal norms restrict women's mobility and voice in decision-making.

“Climate justice is gender justice” — UN Women, 2022

Coping Strategies and Their Limitations

1. Migration : Many smallholder families send members to cities as laborers, disrupting community life and education.

2. Crop Diversification : Farmers switch to hardy or less water-intensive crops, but market support is often lacking.

3. Distress Selling : To manage losses, farmers often sell land, livestock, or produce at below-market prices.

4. Informal Borrowing : In absence of crop insurance, many smallholders rely on informal loans at high interest rates, leading to debt cycles.

Policy Gaps and Systemic Issues

1. Inadequate Insurance Coverage

While crop insurance schemes exist (like PMFBY in India), smallholders often face:

- Complex claim processes
- Delays in payments
- Low awareness or digital access

2. Limited Credit Access

Banks view smallholders as high-risk clients due to lack of collateral.

3. Inadequate Extension Services

Climate-smart advice doesn't reach last-mile farmers due to poor infrastructure or shortage of field officers.

Towards Climate-Resilient Smallholder Agriculture

1. Climate-Smart Agriculture (CSA) : Technologies like stress-tolerant seeds, efficient irrigation, and agroforestry can reduce risks.

Case Study: In Kenya, adoption of drought-tolerant maize increased yields by 30% (CIMMYT, 2021).

2. Improved Market Access : Mobile-based platforms like eNAM (India) and DigiFarm (Africa) help connect farmers to better prices and input markets.

3. Weather and Crop Advisory Systems : AI-based apps like *SHEKRU* and *FarmBeats* provide real-time localized forecasts and crop health alerts.

4. Community-Based Risk Sharing : Cooperative-based insurance and savings groups offer a safety net.

5. Youth Engagement : Digital literacy and agri-tech entrepreneurship can attract rural youth, offering both climate and employment solutions.

Role of International and National Agencies

1. UN and FAO : Offer frameworks like SDG-13 (Climate Action) and promote resilience in smallholder systems.

2. World Bank and IFAD : Fund rural infrastructure, weather insurance, and irrigation schemes.

3. Government Schemes (India)

- **PMFBY** – Crop insurance
- **PKVY** – Organic farming support
- **NMSA** – National Mission for Sustainable Agriculture

Conclusion

Climate change has created an economic burden that smallholder farmers are least equipped to handle, despite their crucial role in food systems. Without focused interventions—technological, financial, and institutional—millions of farmers face a cycle of poverty, food insecurity, and social instability. A climate-resilient future must be inclusive, farmer-centric, and sustainable. By investing in smallholders, we invest in global food security.

“Helping smallholder farmers adapt to climate change is not just about agriculture; it's about justice, economy, and survival.” — *IFPRI, 2022*

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CLIMATE-SMART EXTENSION: BUILDING RESILIENT FARMING COMMUNITIES

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Abstract

Climate-smart extension plays a crucial role in enhancing the resilience of farming communities to climate change. By integrating climate-resilient practices with timely advisory services, it empowers farmers to adapt to unpredictable weather, pests, and resource constraints. This approach combines traditional knowledge with innovations such as ICT tools, climate forecasting, and sustainable agricultural methods. Climate-smart extension not only strengthens adaptive capacity but also supports food security, income stability, and environmental sustainability. Through capacity building, technology dissemination, and institutional support, it fosters resilient farming systems capable of withstanding climate shocks and ensuring long-term agricultural productivity and rural well-being.

Keywords : Climate-smart extension, resilient farming, climate change adaptation, sustainable agriculture, climate-resilient practices

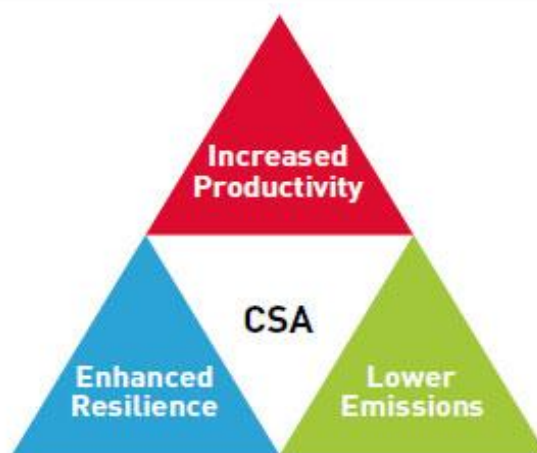
Introduction

Climate-resilient farming communities can anticipate, adapt to, and recover from the adverse effects of climate change, ensuring sustainable livelihoods and food security. This resilience is built through practices like crop diversification, agroforestry, efficient water use, and soil conservation. Technological tools such as weather forecasting and remote sensing empower farmers to make informed decisions. Climate-resilient crops and livestock, combined with institutional support, training, and access to credit, further strengthen adaptive capacity. By adopting these strategies, farming communities reduce vulnerability, protect yields, and build sustainable agricultural systems that can withstand climate shocks and ensure long-term productivity.

Three pillars of Climate-Smart Agriculture (CSA) are:

1. **Productivity**
Increase agricultural productivity and incomes sustainably to support food security and development, especially for smallholder farmers.
2. **Adaptation**
Strengthen the resilience of agricultural systems to climate change by helping farmers adapt to weather variability, pests, and other climate-related risks.
3. **Mitigation**
Reduce or remove greenhouse gas emissions from agriculture wherever possible, through practices like efficient resource use, carbon sequestration, and improved livestock and crop management

The three pillars of Climate-Smart Agriculture



Reference : <https://www.rural21.com/english/news/detail/article/climate-smart-agriculture-what-is-it.html>

Components of Climate-Smart Agriculture

1. **Climate-Resilient Agricultural Practices:** Climate-smart extension promotes sustainable practices such as crop diversification, agroforestry, conservation agriculture, and integrated pest management. These practices reduce vulnerability to climate extremes, enhance soil health, and improve water use efficiency. For example, promoting drought-tolerant or flood-resistant crop varieties can significantly reduce losses in climate-stressed regions.
2. **ICT and Digital Tools:** Information and communication technologies (ICT) have revolutionized extension delivery. Mobile-based advisory services, SMS alerts, mobile apps, and digital kiosks provide timely information on weather forecasts, pest outbreaks, and recommended practices. Remote sensing and GIS tools help in mapping vulnerabilities and providing area-specific advisories.
3. **Capacity Building of farmers:** Training programs, workshops, and field demonstrations equip farmers with the knowledge and skills required to implement climate-resilient practices. Farmer Field Schools (FFS) are particularly effective as they use experiential learning to promote adaptive practices.
4. **Community-Based Approaches:** Climate-smart extension encourages the formation of self-help groups, farmer producer organizations (FPOs), and community resource persons to strengthen peer learning and collective action. These groups serve as local platforms for sharing knowledge, accessing inputs, and advocating for policy support.
5. **Early Warning Systems and Climate Forecasting:** Providing timely and accurate weather forecasts helps farmers make informed decisions on planting, harvesting, and applying inputs. Extension services collaborate with meteorological departments to disseminate agro-advisories tailored to specific regions and crop stages.
6. **Institutional Support and Policy Linkages:** Climate-smart extension is supported by government policies, research institutions, and NGOs that promote climate adaptation strategies. Programs like the National Mission for Sustainable Agriculture (NMSA) and the National Innovations in Climate Resilient Agriculture (NICRA) provide institutional frameworks for implementation.

Some Case Studies of Climate Smart Agriculture on resilient farming:

Case Study 1: India - Promoting Climate-Resilient Crops in Andhra Pradesh

Extension services in Andhra Pradesh have played a key role in promoting climate-resilient farming among smallholders. Through field demonstrations and farmer field schools, they introduced drought-tolerant rice and millets, along with integrated pest management practices. These initiatives led to improved yields and enhanced resilience to climate variability, significantly contributing to regional food security and sustainable agriculture (Joshi et al., 2016).

Case Study 2: Kenya - Enhancing Water Management in Semi-Arid Regions

To support Climate-Smart Agriculture (CSA) in semi-arid regions of Kenya, extension services have promoted efficient water management practices such as rainwater harvesting and drip irrigation. Through community workshops and on-farm training, farmers have learned to optimize water use and reduce wastage. These efforts have improved water use efficiency and helped sustain crop production during dry periods, highlighting the vital role of extension in promoting sustainable farming (Njeru *et al.*, 2016).

Conclusion

Strengthening climate-resilient farming communities is key to addressing the pressing challenges posed by climate change. These communities play a vital role in safeguarding natural ecosystems, ensuring food availability, and sustaining rural livelihoods. Achieving resilience requires a comprehensive approach that blends innovation, inclusive policies, and multi-stakeholder collaboration. Empowering farmers through knowledge sharing, skill development and access to climate-smart technologies is essential. Overcoming social, economic, and institutional barriers demands targeted investments and adaptable strategies. By promoting inclusive, ecosystem-based, and farmer-focused approaches, we can pave the way for a more sustainable agricultural future that supports both people and the planet.

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COST-BENEFIT ANALYSIS OF CLIMATE-ADAPTED AGRICULTURAL VARIETIES

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Abstract

Climate change poses a significant challenge to global agriculture, affecting crop yields, food security, and rural livelihoods. In response, climate-adapted agricultural varieties (CAAVs)—such as drought-tolerant, heat-resistant, flood-tolerant, and salt-tolerant crop cultivars—are being developed and promoted. This article conducts a cost-benefit analysis of these climate-adapted varieties to assess their economic feasibility, social utility, and potential to enhance climate resilience in agriculture. It explores direct and indirect costs, financial and non-financial benefits, and long-term sustainability considerations.

Introduction

Agricultural productivity is highly vulnerable to climate variability and extreme weather events. According to the IPCC (2022), global temperatures are expected to rise between 1.5–2°C by the mid-21st century, leading to altered rainfall patterns, increased frequency of droughts and floods, and greater risks to food security. One of the most promising adaptation strategies is the development and dissemination of climate-adapted agricultural varieties (CAAVs).

CAAVs are crop varieties bred specifically to withstand climatic stresses such as high temperatures, water scarcity, salinity, and submergence. This article evaluates their economic efficiency and utility through a cost-benefit lens, aiming to inform policymakers, researchers, and farmers about the real-world viability of these technologies.

Concept and Types of Climate-Adapted Agricultural Varieties

Climate-adapted varieties include:

- Drought-tolerant varieties (e.g., Drought-Tolerant Maize for Africa - DTMA)
- Heat-tolerant varieties (e.g., wheat cultivars developed by CIMMYT)
- Flood-tolerant rice (e.g., Sub1 rice from IRRI)
- Salinity-resistant crops (e.g., salt-tolerant Basmati rice in India)

These varieties are developed through conventional breeding, marker-assisted selection, or genetic engineering.

Methodology of Cost-Benefit Analysis

A standard cost-benefit analysis (CBA) involves:

- Identification of Costs: Research and development (R&D), seed production, extension services, training, and transition costs.

- Identification of Benefits: Increased yields, reduced input use, resilience to shocks, improved incomes, and long-term sustainability.
- Time Horizon: Typically 5–20 years to capture full benefits.
- Discount Rate: Future benefits are discounted using standard rates (e.g., 5–10%) to reflect time value of money.
- Benefit-Cost Ratio (BCR), Net Present Value (NPV), Internal Rate of Return (IRR): Key indicators for assessing viability.

Costs of Climate-Adapted Varieties

1. Research and Development

Developing climate-resilient varieties requires investment in gene discovery, field trials, and trait selection. For example, the development of drought-tolerant maize under the DTMA project cost approximately USD 30 million over 10 years (CIMMYT, 2015).

2. Seed Production and Distribution

Ensuring high-quality seeds reach farmers involves costs in seed multiplication, certification, and supply chain logistics.

3. Farmer Training and Extension

Successful adoption depends on farmer awareness and training in new agronomic practices, especially when varieties require specific inputs or methods.

4. Opportunity and Transition Costs

Farmers face potential losses during the transition period, especially if new varieties underperform due to unfamiliarity or lack of input access.

Benefits of Climate-Adapted Varieties

1. Yield Stability and Increase

Multiple studies confirm that CAAVs stabilize yields during climate stress. For instance, Sub1 rice can yield 1.0–1.5 t/ha more than traditional rice under submergence (IRRI, 2013).

2. Input Cost Reduction

Many CAAVs are more efficient in water or fertilizer use, reducing input costs and environmental impact.

3. Economic Returns

The DTMA project estimated an annual benefit of USD 160 million across 13 African countries, primarily from yield increases (La Rovere *et al.*, 2014).

4. Risk Reductions

Reduced crop failure risk allows better access to credit and investment in farm assets, promoting long-term growth.

5. Food Securities and Nutrition

Higher and more stable production contributes to regional food availability and dietary diversity, especially in vulnerable regions.

Empirical Case Studies

1. Drought-Tolerant Maize in Sub-Saharan Africa

Benefit-Cost Ratio (BCR): 3.4

NPV (10 years): USD 470 million

Key Findings: Farmers adopting DTMA experienced yield gains of 25–30% in dry years, improved household food security, and enhanced income stability.

(Source: La Rovere *et al.*, 2014)

2. Sub1 Rice in India and Bangladesh

BCR:4.5

Yield Benefit: +1.5 tons/ha under flood conditions

Adoption Area (as of 2021): >5 million hectares

Socioeconomic Impact: Greater food availability during monsoon floods, especially in Eastern India.

(Source: Dar *et al.*, 2013; IRRI, 2021)

Challenges in Cost-Benefit Assessment

- **Uncertain Climate Projections:** Difficulty in accurately modeling future weather patterns affects BCA outcomes.
- **Data Gaps:** Lack of disaggregated field data limits accurate estimation of both costs and benefits.
- **Adoption Heterogeneity:** Benefits vary across regions, farming systems, and socio-economic groups.
- **Market and Policy Barriers:** Inadequate seed distribution, pricing policies, or subsidy misalignment can limit benefit realization.

Policy and Institutional Considerations

Governments and institutions can improve cost-benefit outcomes by:

- Investing in localized varietal development and testing
- Supporting public-private seed delivery systems
- Strengthening extension services
- Providing risk insurance and credit linked to climate-adapted technologies
- Subsidizing initial adoption to offset transition costs

Environmental and Social Externalities

1. Positive Externalities

- Reduced groundwater usage (in drought-tolerant crops)
- Lower greenhouse gas emissions from input-efficient varieties
- Enhanced biodiversity through conservation of local germplasm

2. Negative Externalities

- Risk of genetic uniformity and vulnerability to new pests/diseases
- Intellectual property issues (e.g., seed sovereignty concerns)

Long-Term Sustainability

For long-term cost-benefit success, CAAVs must be:

- **Scientifically sound:** Genetically stable and resistant to evolving stresses
- **Socially inclusive:** Benefitting smallholders, women, and marginal communities
- **Economically viable:** Supported by robust supply chains and market access

Integrating CAAVs into climate-smart agriculture (CSA) frameworks enhances their overall impact and ensures sustainability.

Conclusion

Climate-adapted agricultural varieties present a high-return investment for climate resilience in agriculture. Despite initial costs in development and dissemination, the long-term economic, environmental, and social benefits significantly outweigh them. For countries like India, Bangladesh, and many Sub-Saharan nations facing acute climate risks, scaling CAAV adoption through targeted investment and policy support offers a pragmatic path to sustainable food security and rural prosperity.

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CRISPR–CAS DELIVERY STRATEGIES IN PLANTS

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Abstract

The success of CRISPR–Cas-based genome editing in plants hinges on the efficient delivery of editing reagents into plant cells, a process complicated by the presence of the rigid plant cell wall and the diversity of plant tissue types. Various delivery methods have been developed, each with unique advantages and limitations, to introduce DNA, RNA, or ribonucleoprotein (RNP) complexes of CRISPR–Cas systems into plant cells. The current delivery strategies ranging from *Agrobacterium*-mediated transformation and biolistic bombardment to emerging technologies like nanoparticle- and viral vector-mediated delivery. Additionally, it highlights the potential of protoplast transformation and organelle-targeted editing, offering insights into their mechanisms, applications, and future prospects in plant genome engineering.

Keywords: CRISPR–Cas, delivery strategies, *Agrobacterium*, vector mediated

Introduction

CRISPR–Cas reagent delivery in plants Effective application of CRISPR–Cas9 in plants requires a robust and universal way of delivering CRISPR–Cas reagents into plant cells However, both of the widely used delivery methods on which plant transformation has relied for decades biolistic bombardment and *Agrobacterium*-mediated delivery have limitations. Biolistic bombardment can deliver genetic material through rigid cell walls by mechanical force, but it is restricted by its low efficiency and can damage genome sequences. *Agrobacterium* bacteria can infect a large range of plants, but the integration of foreign DNA is unavoidable, and transformation efficiency is greatly affected by the recipient genotype, especially in monocots (Ran *et al.*, 2017). Furthermore, none of these conventional methods can avoid lengthy tissue culture procedures. Consequently, novel delivery strategies are urgently needed (Fig.1).

1. *Agrobacterium*-Mediated Delivery

Agrobacterium tumefaciens, a naturally occurring soil bacterium, is a well-established biological tool for plant genetic engineering. It exploits its type IV secretion system to transfer T-DNA from its plasmid into the nuclear genome of plant cells. In CRISPR–Cas applications, T-DNA vectors are engineered to carry the Cas9 or Cas12a gene and sgRNA expression cassettes under the control of plant-compatible promoters.

Agrobacterium-mediated transformation is primarily used for the stable integration of CRISPR constructs into the host genome, which ensures long-term expression and facilitates the recovery of edited lines through tissue culture and regeneration. This method is particularly effective in dicotyledonous plants like *Arabidopsis thaliana*, *Nicotiana benthamiana*, and tomato. However, monocots such as maize and wheat exhibit lower transformation efficiencies, necessitating protocol optimization.

Advantages:

- High transformation efficiency in some plant species

- Well-established for stable gene integration
- Suitable for generating heritable edits

Limitations:

- Risk of random integration of T-DNA
- Less effective in recalcitrant monocots
- Longer timelines due to tissue culture requirements

2. Biolistic Bombardment (Particle Bombardment)

Biolistic delivery, commonly known as gene gun or particle bombardment, is a physical method that involves propelling gold or tungsten particles coated with DNA, RNA, or RNPs into plant cells using high pressure. This approach is capable of breaching the tough plant cell wall, making it widely applicable across various plant species, including those less amenable to *Agrobacterium* transformation.

It is particularly useful for delivering CRISPR reagents into both nuclear and organellar genomes. For instance, chloroplast genome editing is typically performed using biolistics, as the organelle-targeted transformation is challenging via biological vectors.

Advantages:

- Bypasses species-specific transformation barriers
- Suitable for both stable and transient transformation
- Applicable to nuclear, plastid, and mitochondrial genomes

Limitations:

- Can cause tissue damage
- May result in low transformation efficiency
- Requires expensive equipment and regeneration protocols

3. Nanoparticle-Mediated Delivery

Nanotechnology offers a non-integrative and potentially DNA-free method for CRISPR delivery. Various nanocarriers such as carbon nanotubes, silica nanoparticles, layered double hydroxides (LDHs), and liposomes can be engineered to carry and protect nucleic acids or proteins. These particles facilitate the passive or active transport of CRISPR reagents through the plant cell wall and membrane.

Recent advancements include functionalization of nanoparticles for targeted delivery (e.g., to chloroplasts) and stimuli-responsive release. Notably, single-walled carbon nanotubes (SWCNTs) have shown promise in delivering DNA and RNPs to mature plant leaves without transgene integration or tissue culture, thus supporting transgene-free genome editing.

Advantages:

- Minimally invasive, DNA-free approach
- Enables transient expression without integration
- Broad species applicability

Limitations:

- Technology still in early developmental stages for plants
- Concerns regarding nanoparticle toxicity and biosafety
- Delivery efficiency varies with plant species and tissue type

4. PEG-Mediated Protoplast Transformation

Protoplasts are plant cells with their cell walls enzymatically removed, making them highly amenable to the uptake of macromolecules. In PEG-mediated transformation, protoplasts are incubated with DNA, RNA, or RNPs in the presence of polyethylene glycol, which transiently permeabilizes the plasma membrane and promotes uptake.

This method is extensively used for testing genome editing constructs, optimizing sgRNAs, and conducting transient assays. Delivery of RNPs into protoplasts is particularly attractive for achieving DNA-free genome editing, reducing off-target effects and eliminating regulatory concerns associated with foreign DNA.

Advantages:

- High transformation efficiency
- Allows transient expression and rapid assay of editing outcomes
- Ideal for DNA-free genome editing

Limitations:

- Regeneration of whole plants from protoplasts is challenging and species-dependent
- Labor-intensive and technically demanding
- Limited to experimental and proof-of-concept applications

5. Viral Vector-Mediated Delivery

Engineered plant viruses can be used as vectors for delivering CRISPR–Cas reagents. Viral vectors such as Tobacco rattle virus (TRV), Bean yellow dwarf virus (BeYDV), and Foxtail mosaic virus (FoMV) can systemically infect plants and move between cells via plasmodesmata, enabling widespread delivery of sgRNAs or Cas constructs.

This approach is particularly valuable for achieving high-efficiency, tissue-wide genome editing without requiring stable transformation or tissue culture. In plants with pre-integrated Cas genes, viral vectors can deliver sgRNAs alone, allowing targeted and heritable edits.

Advantages:

- Tissue culture-independent delivery
- Rapid and systemic spread within the plant
- Suitable for multiplexed and high-throughput editing

Limitations:

- Limited cargo capacity restricts delivery of large Cas proteins
- Often transient and may not support heritable edits
- Host range is virus-dependent

Conclusion

The delivery of CRISPR–Cas systems into plant cells remains a critical determinant of editing success. While *Agrobacterium*-mediated transformation and biolistics remain dominant, innovative approaches such as nanoparticle carriers, RNP complexes, and viral vectors are expanding the toolkit for plant genome engineering. The choice of delivery strategy must consider species-specific transformation efficiency, editing goals (transient vs. stable), and regulatory implications. Future research should aim to enhance delivery efficiency, minimize tissue culture dependency, and enable high-throughput and multiplexed genome editing in diverse crop species.

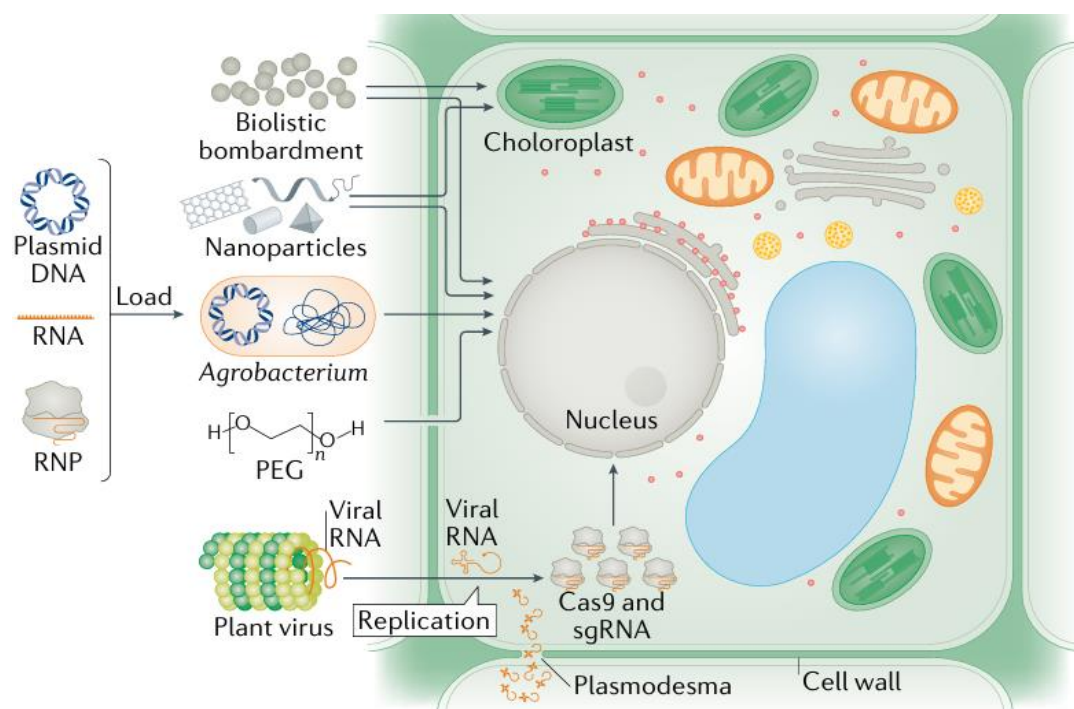


Figure.1. Direct CRISPR–Cas delivery

Source: Zhu, H., Li, C. & Gao, C. 2020

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CLIMATE SMART VILLAGES: TRANSFORMING RURAL RESILIENCE THROUGH LOCALLY LED INNOVATION

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Abstract

Communities, researchers, and development partners evaluate local climate-smart agriculture (CSA) solutions in Climate Smart Villages (CSVs). CSVs cover South and Southeast Asia, West, East, and Southern Africa, and Latin America and were launched by CCAFS in 2012. This “field laboratory” strategy uses better crop varieties, water management, renewable energy, and locally inclusive governance to fulfil CSA's triple goals of productivity, resilience, and greenhouse gas reduction. Early results include higher agricultural and livestock yields, earnings, soil fertility, and fuel savings. Solar irrigation in Jharkhand, India; agroforestry and goat-rearing in Kenya's Lower Nyando Basin; policy-backed projects in Nepal; and rice-smart valley systems in West Africa are prominent CSV implementations. Despite scaling constraints including funding, policy integration, and institutional capacity, the CSV model's participatory structure, synergy with national plans, and alignment with Sustainable Development Goals make it a potent climate-smart rural development model.

Introduction

Climate threats erratic rainfall, floods, droughts, and high heat events, threaten food security, livelihoods, and environmental sustainability for rural smallholders in Asia, Africa, and Latin America. More frequent climatic extremes, according to the IPCC, would reduce agricultural production and increase poverty in susceptible countries. Climate-smart technologies like stress-tolerant seedlings and precision irrigation are being created worldwide, but mismatches with local agroecological conditions, insufficient extension services, costly finance, and restrictive development strategies hinder their use. Traditional research methodologies often use “one-size-fits-all” solutions without farmer or community participation. In 2012, CCAFS established CSV as part of its Climate-Smart Agriculture (CSA) portfolio to fill this gap. CSVs are community-based “platforms” where smallholders, researchers, governmental institutions, and NGOs co-design, pilot, and evaluate numerous interventions across multiple seasons. CSVs seek realistic, scalable solutions by expressly customizing CSA packages to local conditions and co-deploying them with communities (Aggarwal *et al.*, 2013; Ghimire, 2022).

CSVs pursue three interlinked goals:

1. **Increased productivity** through improved technologies and practices.
2. **Resilience** by enhancing the capacity to withstand and adapt to climate variability.
3. **Mitigation** by integrating low-carbon practices and energy solutions.

Beyond agricultural outcomes, CSVs strengthen social capital, foster inclusive decision-making, and generate practical evidence, both qualitative and quantitative, that feeds into policy, financing instruments, and broader climate adaptation strategies.

The Framework and Methodology of CSVs

Designing Locally Relevant Interventions

From the outset, CSVs eschew universal packages in favour of context-specific strategies tailored through a robust six-step research-for-development process:

1. **Site Selection:** Targeted to climate hotspots and characterized by high vulnerability.
2. **Baseline Assessments:** Surveys of socio-economic, agronomic, climatic, and infrastructural conditions.
3. **Multi-stakeholder Planning:** Local committees include farmers, women's groups, youth, government agents, and researchers, ensuring a diversity of perspectives, from priority setting to defining activities.
4. **Technology Choice and Experimentation:** Interventions range from improved seeds and livestock to water harvesting, energy solutions, and digital climate advisories; these are frequently trailed in comparative plots or village-wide demonstrations.
5. **Monitoring and Evaluation:** Performance metrics include yield, income, resilience, GHG emissions, gender inclusion, and capacity.
6. **Learning and Scaling:** Promising interventions are replicated across nearby villages and scaled up through policy integration and partnerships.

This approach has been deployed initially in Africa and South Asia (2012), later expanding into Southeast Asia, Latin America, and public-sector scaling efforts in the mid-2010s.

Core Components

1. Climate-Smart Agriculture (CSA)

CSVs experiment with combinations of:

- **Stress-tolerant seeds** (drought, flood, or salinity-tolerant varieties).
- **Soil fertility practices:** Integrated nutrient management, compost, agroforestry, alley cropping.
- **Pest and weed control:** Integrated pest management.
- **Diversification:** Intercropping cereals with legumes or high-value crops.
- **Livestock improvements:** Better breeds, fodder trees, feed supplements, and improved milk storage or processing.

Field studies across East Africa report soil nutrient levels (N, P, K) 50–80% higher under CSA systems than control plots.

2. Water Management

Adaptation strategies vary by local climate:

- **Rainwater harvesting:** Ponds, farm dams, roof terraces.
- **Drainage infrastructure:** Especially in flood-prone areas (e.g., Bihar, India).
- **Contour bunds, terraces:** Reduce runoff & erosion.
- **Irrigation:** Solar-powered pumps and micro-irrigation systems.

3. Renewable Energy and Clean Technology

Energy innovations are integrated to support agriculture and livelihoods:

- **Solar pumps** for irrigation, e.g., the Jharkhand pilot eliminated diesel.
- **Biogas digesters** and biomass for clean cooking.

- **Microgrids or pico-hydro systems** in off-grid rural settings.

4. Information Services and ICT

CSV platforms blend technologies with knowledge:

- **Weather forecasts and advisories** via mobile phones.
- **Index-based crop insurance.**
- **Digital platforms** to exchange local innovations, extension info, and market access.

An example in Ghana/Burkina Faso showed effective cross-visits informed by “climate analogue” tools to help neighbouring climate-vulnerable communities.

5. Inclusive Governance and Social Inclusion

CSV’s participatory governance is foundational:

- **Local CSV committees** coordinate trial planning, monitoring, and evaluation.
- **Empowerment of women and youth** through targeted trainings, leadership roles, and advisory positions—observed in Ghana, Tanzania, India, and East Africa.
- A “train-the-trainer” model amplifies learning, often culturally adapted (e.g., training

Benefits

Dimension	Observed Benefits
Productivity	Yield increases (cereals, legumes, livestock due to improved breeds/fodder)
Income	Case studies in India and Africa show a doubling of incomes
Climate Resilience	Buffering from drought/floods, diversified cropping, and energy supply
Environmental Health	Improved soil nutrients, reduced erosion, lower emissions from diesel/wood
Social Inclusion	Women and youth empowered; local governance strengthened
Policy Spillover	Integration into national rural and climate change strategies (e.g., Nepal, Vietnam)

Challenges

1. **Scaling and Financing** -Many CSV pilots rely on funding from CGIAR or partners. Solar pumps, irrigation infrastructure, and ICT systems incur upfront costs; poor farmers often lack credit access.
2. **Institutional and Policy Support** - Nepal and Vietnam institutionalized CSV principles; in other countries, progress remains slow.
3. **Extension Capacity**- CSVs depend on strong extension services; in areas lacking support, results may stagnate.
4. **Monitoring and Evidence**- Longitudinal, quantitative data is rare outside small-scale evaluations; broader trials and robust metrics are needed to convince policymakers and investors.
5. **Social Equitability and Inclusion**- Despite built-in inclusivity, power imbalances (e.g., landless farmers, gender inequality) may still limit benefits to more privileged group members.

Conclusion

Climate Smart Villages (CSVs) are transforming climate adaptation and rural development by integrating agriculture, water access, renewable energy, local knowledge, and inclusive government.

They have shown improvements in yields, incomes, soils, and community welfare in countries like India, Nepal, Kenya, and West Africa. However, scaling CSVs requires stable financial models, strong policies, empowered institutions, and innovative technology. CSV models can help expand climate resilience, aligning with UN Sustainable Development Goals. The future of CSVs involves building networks, expanding finance, improving monitoring methods, and using digital advances.

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APPLICATION OF DRONE TECHNOLOGY FOR PESTICIDE APPLICATION

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Introduction

Drone technology has rapidly emerged as a powerful tool for pesticide application in agriculture, significantly enhancing precision agriculture efficiency and safety compared to traditional methods. Agricultural drones designed for spraying are essentially Unmanned Aerial Vehicles (UAVs) equipped with GPS and specialized spraying systems. By utilizing drones, farmers can reduce chemical waste, minimize human exposure to hazardous substances, and optimize resource allocation. This technology allows for targeted application, variable rate spraying, and seamless integration with data analytics platforms for monitoring and analysis.

Mechanism of drone operation

Drone application methodologies involve using unmanned aerial vehicles (UAVs) for various tasks, often involving data collection and analysis. Key aspects include flight planning, sensor integration (cameras, LiDAR, thermal), data acquisition, processing, and application-specific analysis. These methods are employed across diverse fields like agriculture, construction, and disaster response.

1. Flight Planning:

A. GPS/GNSS Navigation: Farmers or operators use sophisticated software to plan precise flight paths for the drone. This involves mapping the field, identifying areas that require treatment and programming the drone's route, altitude, and speed.

B. Autonomous Flight: Most modern agricultural drones operate autonomously once the flight plan is uploaded. They use GPS and AI-powered systems to follow the pre-programmed route with high accuracy.

C. Obstacle Avoidance: Advanced drones incorporate sensors (e.g., LiDAR, radar) to detect and avoid obstacles like trees, power lines, and buildings, ensuring safe operation.

2. Pesticide Carrying and Distribution:

A. Tank and Pump System: Drones carry a liquid tank (typically 10-30 L for smaller to medium-sized agricultural drones) filled with the diluted pesticide solution. An electric pump draws the liquid from the tank.

B. Nozzles: The liquid is then directed through a set of precision nozzles, usually located on booms extending from the drone's arms or directly beneath the rotors. These nozzles are designed to produce a specific droplet size and spray pattern.

C. Controlled Release: The spray rate is precisely controlled, often adjusted in real-time based on the drone's speed and the required application volume per unit area.

3. Spray Pattern and Downwash Effect:

A. Rotor Downwash: A unique advantage of multi-rotor drones is the strong downwash generated by their propellers. This downwash pushes the spray droplets downwards, helping them penetrate dense crop canopies and ensuring better coverage of the target plants, even on the undersides of leaves. This also helps reduce spray drift.

B. Uniform Coverage: By maintaining a consistent altitude and speed, and with carefully designed nozzle configurations, drones can achieve highly uniform spray coverage across the target area.

4. Real-time Monitoring and Adjustment:

Sensors and Cameras: Some advanced spraying drones integrate real-time sensors (e.g., multispectral cameras) that can monitor crop conditions during the spraying process.

Variable Rate Application (VRA): If integrated with crop health data, the drone can even adjust the spray volume or concentration dynamically, applying more pesticide where needed (e.g., high pest infestation areas) and less in healthy areas, further optimizing resource use.

Advantages of Drone Technology for Pesticide Application

1. Precision and Targeted Application:

A. Reduced Chemical Waste: Drones apply pesticides exactly where and when needed, minimizing over-application and ensuring chemicals are not wasted on healthy areas or non-target vegetation.

B. Minimized Drift: Flying at low altitudes (typically 1.5-2.5 meters above the canopy) and utilizing rotor downwash reduces spray drift, preventing contamination of adjacent fields, water bodies, and non-target organisms.

C. Data-Driven: Integration with precision farming data (from drone mapping, satellite imagery, or sensors) allows for highly customized application based on specific crop needs.

2. Increased Efficiency and Speed

A. Rapid Coverage: Drones can cover large areas significantly faster than manual spraying.

B. Time and Labor Savings: This speed translates directly into reduced labor costs and allows for timely application, which is crucial during critical pest or disease outbreaks.

C. Accessibility: Drones can easily access fields that are difficult or impossible for ground-based machinery (due to wet soil, steep slopes, or dense crops), enabling timely intervention regardless of terrain or weather conditions that would ground traditional equipment.

3. Improved Safety:

A. Reduced Human Exposure: Farmers and workers are not directly exposed to harmful chemicals, significantly reducing health risks associated with pesticide handling and spraying. Operators control the drone remotely from a safe distance.

B. No Soil Compaction: Unlike heavy ground machinery, drones do not compact the soil, preserving soil health and structure.

4. Environmental Benefits:

A. Lower Chemical Footprint: Precision application drastically reduces the overall quantity of pesticides used, leading to a smaller environmental footprint.

B. Water Conservation: Many drone spraying systems use ultra-low volume (ULV) application techniques, requiring significantly less water for dilution compared to traditional spraying methods.

5. Cost-Effectiveness (Long Term): While the initial investment in drone technology can be high, the long-term savings from reduced chemical usage, lower labor costs, and potentially increased yields (due to effective and timely intervention) can make it a very cost-effective solution.

Challenges And Considerations

- 1) **Battery Life and Payload:** Current drone battery technology limits flight time and payload capacity, requiring frequent battery changes and refills for large fields.
- 2) **Regulatory Hurdles:** Regulations regarding drone flight, weight limits, line-of-sight operation, and pesticide application vary by region and can be complex. In India, while the government is promoting drone use, obtaining necessary permits and adhering to SOPs is crucial.
- 3) **Technical Expertise:** Operating and maintaining agricultural drones, along with interpreting the data they collect, requires specialized training and technical knowledge.
- 4) **Initial Investment Cost:** The upfront cost of purchasing advanced agricultural drones and associated software can be significant for individual farmers, especially smallholders.
- 5) **Weather Dependence:** Drones are sensitive to strong winds, rain, and extreme temperatures, which can affect spray efficacy and safe operation.
- 6) **Pesticide Labeling:** Not all pesticide labels currently include instructions for drone application, which can create a legal hurdle for farmers.
- 7) **Spray Drift Assessment:** While drones aim to reduce drift, factors like droplet size, wind conditions, and flight parameters need to be carefully managed to ensure minimal off-target movement.

Drone Pesticide Application in India : India has been actively promoting drone use in agriculture, recognizing its potential to transform the sector.

- **Government Initiatives:** The Ministry of Agriculture & Farmers Welfare has issued Standard Operating Procedures (SOPs) for drone application of pesticides and nutrients. Subsidies are also provided under schemes like the Sub-Mission on Agricultural Mechanization (SMAM) to make drones more accessible.
- **"Kisan Drones":** The concept of "Kisan Drones" (Farmer Drones) is being pushed to facilitate large-scale adoption, particularly benefiting small and marginal farmers through a "Drone as a Service" (DaaS) model.
- **SOP Guidelines:** The SOPs cover critical parameters like:
 - **Drone Flying Speed:** Typically, 4.5-5.0 m/s for spraying.
 - **Height above Crop Canopy:** Generally, 1.5-2.5 meters.
 - **Water Volume:** Specific recommendations for different crop stages (e.g., 5-10 l/ha for early stage, 15-20 l/ha for late stage).
 - **Nozzle Type and Droplet Size:** Anti-drift flat fan nozzles are recommended, with specific droplet size ranges for insecticides (250-350 µm) and fungicides.
 - **Suitable Time of Spray:** Avoiding hot parts of the day and periods of high wind (e.g., 6 am - 10 am and 3 pm - 6 pm in summer/rainy season) and avoiding spraying during the flowering stage to protect pollinators.
 - **Environmental Conditions:** Specific limits for temperature (under 35°C), humidity (over 50%), and wind speed (under 3 m/s).

Conclusion

Overall, drone technology is rapidly becoming an indispensable tool for pesticide application, offering a precise, efficient, and safer alternative that aligns well with the principles of sustainable agriculture and modern farming practices.

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EARLY DISEASE DETECTION IN LIVESTOCK ANIMALS AND MITIGATION STRATEGIES BY FARMERS

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Livestock are central to the livelihoods of smallholder farmers in India and many other developing countries. Whether it's cattle, goats, poultry, or pigs, these animals provide food, income, nutrition as well as security. Healthy animals grow well, produce more milk, eggs, or meat, and reproduce better. If illness goes unnoticed, it can spread rapidly through the herd or flock, reducing productivity or causing losses. Recognizing the early signs of disease is crucial for timely treatment, reducing the spread of infections, and minimizing the economic losses of farmer. With a little awareness, daily observation and quick action, farmers can protect their herds and ensure the health of their animal and consistent productivity.

General Signs of Illness among all livestock can be helpful at a very preliminary stage like the loss of appetite (refusal to eat or drink), unusual behaviour (isolation from the herd/flock and Lethargy or excessive aggression), Changes in Body Condition (sudden weight loss or gain, Dull coat, swelling in any part of the body), Abnormal Posture or Movement (limping, staggering, stiffness), Discharge from Eyes, Nose, or Mouth (mucus, pus, or foam), Coughing, Sneezing, or laboured Breathing, Changes in Faeces or Urine (Diarrhoea, blood, unusual colour or smell) and decreased milk/egg production.

Besides daily watching, specific physical checks can be done by the farmers fortnightly or monthly. Like inspecting animals for warmth, swelling, or sores in any part of the body, checking eyes and gums for pale colour which indicate anaemia or parasitic infestation. Farmers can even use a thermometer to look for fever that might be due to infection. Body weight can also be monitored for keeping an eye on sudden drop and maintain a data book. These simple checks can help farmer's spot illness even before it becomes obvious.

When an animal shows signs of illness, farmers can isolate the sick animal to prevent it from infecting others and provide them clean water and easy-to-digest feed to help it recover. Secondly, the animal can be kept in comfortable condition with clean bedding and shelter. Keep warm in cold weather or cool in heat. And then the rest of the animals can be thoroughly checked for similar symptoms.

Stopping all animal movement immediately and reporting the suspected infection or outbreak to the local veterinarian, any government veterinary services or animal health department is the next crucial step that should be taken by the farmer.

Preventing disease is easier than treating it, which can be achieved maintaining cleanliness. Following the practices like

- Removing the manure and wet bedding regularly, clean feeding and watering containers to prevent contamination, protecting feed from rodents and insects, ensuring the control of wild birds, rats, and pests that can spread disease.

- Using separate tools for sick animals to avoid spreading germs and disposing the dead animals properly, by burying or burning away from water sources.
- Following the vaccination and deworming schedules as advised by local authorities.
- Document animal movements, symptoms, and interactions.
- These records help trace and contain outbreaks effectively.

Role of Government in making farmers aware about the disease diagnosis at early stage:

Agricultural universities and Krishi Vigyan Kendras (KVKs) play a vital role in educating farmers about livestock diseases, their early identification, and effective control measures. Through targeted outreach programs, on-farm demonstrations, and farmer training camps, these institutions bridge the gap between scientific research and rural practice. They can disseminate knowledge about common and emerging livestock diseases using local languages and practical examples, making information accessible and relevant. Regular workshops, mobile veterinary clinics, and distribution of disease identification charts and vaccination schedules help farmers recognize early signs of illness and take prompt action. Moreover, collaboration with local veterinarians and use of community radio, whatsapp groups, and social media platforms ensure wider reach and real-time updates during outbreaks. By empowering farmers with knowledge, agricultural universities and KVKs strengthen disease surveillance, encourage timely vaccination, and promote overall herd health management, contributing significantly to the sustainability of the livestock sector.

Healthy livestock are the foundation of a successful smallholder farm. Early detection of disease, backed by quick action and clean practices, keeps animals strong and production steady. By observing daily, doing routine checks, isolating sick animals, maintaining hygiene, and keeping simple records, farmers can protect their animals without needing expensive tools. When in doubt, ask for veterinary advice. Good habits and vigilance are a farmer's best defense. With these steps, your animals will stay healthier, your income will be more secure, and your farm will be more resilient year after year.

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THE HIDDEN COSTS OF STORED FEED: WHAT YOU NEED TO KNOW

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Introduction

As the population is increasing day by day, the demand for fish is also increasing, which ultimately increases the demand for fish feed. Survey says by 2050, aquaculture is projected to expand and intensify further, almost doubling its current production. To sustain the production level large amount of feed will be needed in the long run. The lion's share of the production cost is contributed by feed and if this very valuable commodity is kept in adverse condition, it will become susceptible to deterioration, which will eventually bring extra pressure on the fish producers and will have to face loss. Deterioration of feed material is caused by three major factors during storage including Physical factor (moisture, temperature, light, etc.), Biological factor (Insects, rodents, Fungi, etc.), and Chemical factor (Rancidity, fermentation, etc.), that leads to the various kinds of losses such as weight loss, quality loss, health risk, and economic loss.

To get rid of all these losses a proper safety measure should be taken during the storage of feed material that will help producers to produce high-quality fish and gain additional profit.

Deterioration changes during the feed storage

Deteriorating factors bring various changes in the feed material during storage. Following are the major categories of changes occurring in the feedstuffs during storage:

- a) Weight loss,
- b) Quality loss,
- c) Health risk, &
- d) Economic loss.

These losses of feed material are caused by three major factors and some miscellaneous minor factors depicted below

- a) Deterioration due to biological factors,
- b) Deterioration due to physical factors, &
- c) Deterioration due to chemical factors

Deterioration due to biological factors

This loss emerges from the foraging activities of insects, micro-organisms, and animals; these organisms directly eat or destroy the feedstuffs that cause extensive weight loss and quality damage. Deteriorated feedstuffs become susceptible to mould growth, which leads to the complete destruction of feed material and give rise to serious health risk if fish are fed on this moulded feed.

The following are biological factors responsible for deterioration during storage:

1. Insects : Almost all fish feed material attracts insects if it is not stored properly. Insects directly eat or destroy the feedstuffs that cause extensive weight loss. Along with this it also contaminates feed with its faeces, webbing, body parts, and foul odours. A large number of various grain insects

are involved in the destruction of stored feed but among all beetles and moths have the most devastating effect. Sometimes infestation of insects cause extreme heating of grain and if density of insects population is so high then the temperature increases up to 45°C and if insects infestation is associated with microbes, mostly fungi, temperature may reach nearly around 75 °C, causing extensive spoilage and, seldom, spontaneous combustion.

Most common insects cause the destruction of cereal grains, oil seed cakes & meals, and pulses. etc.

	Scientific name	Common name	Opt. RH	Opt. temp. range
	<i>Sitophilus spp.</i>	Weevils	50	26-30
	<i>Sitotroga cerealella</i>	Grain moth	30	26-30
	<i>Tribolium spp.</i>	Flour beetles	*	30-33
	<i>Oryzaephilus spp.</i>	Saw-tooth grain beetles	21	31-34
	<i>Cryptolestes spp.</i>	Flat grain beetles	50	30-33
	<i>Cadracantella</i>	Tropical warehouse moth	25	28-32
	<i>Rhizoperthadomina</i>	Lesser grain borer	30	32-35

	Scientific name	Common name	Opt. RH	Opt. temp. range
	<i>Trogoderma granarium</i>	Khapra beetle	*	33-37

➤ **Factor affecting the insect infestation**

Physical factors like temperature, moisture level, relative humidity, Air, and some other factors such as the origin of insects, food availability, condition of feed ingredients, etc., decide the infestation and flourishing of insects during storage. Among all relative humidity, moisture content of feed ingredients, and temperature of the warehouse are the major deciding factor for the infestations.

Drying below 16% moisture level, make feed grain hard which makes it less susceptible to get attacked by insects. Not all insects are able to harm fully dried kernels of feed grains. Processing techniques such as making cakes or hard flakes are more resistant to the attack and if it is bigger particle then insects will not be able to eat and will be more safe.

Factor affecting the insect infestation		
1.	Temperature	Most of the harmful insects are tropical species and flourish at an optimum temperature of about 28°C.
2.	Relative humidity	Up to 70 percent RH, insects multiply progressively but beyond 70% RH, along with insects, mould formation also takes place which grains more susceptible to deterioration.
3.	Moisture level	16% or above moisture level makes ingredients soft and make more susceptible to deterioration.
4.	Feeding Habits of Insects	Some insects are highly specific about the portion of grains on which they will attack but others do not show that much selectivity and eat voraciously. For example, surface or closely associated portion to the surface of grain is eaten by moth larvae but beetles do not show specificity and destroy the whole grain. A silk webbing over the grain surface is mostly seen when grain is attacked by larvae and it also forms some byproducts that create hindrance in handling and processing.

Losses due to the insect infestation

▪ **Weight loss**

This is the most important loss caused by insects as they directly feed on grains. Presence of frass on the surface of sac shows the feeding activity of insects. Higher value of some physical factors such as temperature, humidity, softness, and nutritive value of the feed materials, are conducive to insect damage. Prolonged storage and failure to maintain the storage area clean make feed gains more labile to insects' infestation and causes weight loss.

▪ **Quality loss**

This loss is also considered one of the most important losses caused by insect attacks. Quality loss can be of multiple types; Chemical changes in the stored feed material are one of the common ones

that impart alteration in flavor and nutritive value. Insects also secrete some enzymes such as lipase that causes additional deterioration of feed material.

Some grains are rich in lipids, which with time of storage tends to break down that act as an attractant to the insects, further breakdown is accelerated by insects that provide a suitable substrate for micro-organism and assist their outbreak which leads to the increment of temperature and moisture level of the stored feed material. An increase in free fatty acids after the breakdown of fat causes enhancement in the off-flavors that is not get accepted by the fish. Attack after the scavenging insects, like cockroaches, supports the outbreak and development of pathogenic bacteria such as Salmonella.

▪ Controlling methods

A relationship exists between the ambient climate condition and insect growth; if the climate is kept congenial to the insects, then growth will be supported, if not then the growth of insects will be hampered. Fully eradicating insect populations from the storehouse of the feed material is not possible, but proper suitable control measures and vigilance can keep the degree of infestation at a manageable level. If Heavy infestation is found in the ingredient sack, then it should not be brought inside the warehouse, but if brought then it should be kept separately. Sweeping up spilled material is one of the good housekeeping techniques that help in checking the scavenger insects as well as rodents that can harm the feed ingredients. Use Insecticides such as Diatomaceous earth, Phosphine, Carbamates, etc. if heavy infestation.

1. Rodents



Rats



Squirrel



Groundhogs

Rodents can have a significant impact on the storage of feedstuff and depicted below are some ways rodents can affect the storage of feedstuff:

1. Contamination: Rodents can contaminate feedstuff by urinating, defecating, and shedding hair. This can introduce bacteria, viruses, and parasites into the feed, making it unsafe for consumption by animals. Contaminated feed can lead to disease outbreaks among livestock, reduced growth rates, and even death.

2. Food Loss: Rodents have a voracious appetite and can consume and spoil a considerable amount of feed. They can chew through bags, containers, and even bulk storage structures, causing spillage and loss of feed. This can result in financial losses for farmers and feed producers.

3. Quality Degradation: Rodents often gnaw on feedstuff, damaging the integrity and quality of the feed. They may contaminate whole grains, pellets, or other feed forms, making them less appealing to animals. This can lead to reduced feed intake, poor animal performance, and increased feed wastage.

4. Structural Damage: Rodents are notorious for their gnawing behavior, and they can damage the structures used for feed storage. They can chew through wooden bins, plastic containers, wiring, and insulation, compromising the structural integrity of storage facilities. This damage may necessitate costly repairs and increase the risk of accidents such as collapse or fire.

5. Disease Transmission: Some rodents carry diseases that can be transmitted to livestock, such as leptospirosis, salmonellosis, and hantavirus. If rodents have access to feed storage areas, they can contaminate the feed with pathogens, potentially leading to the spread of diseases among animals.

Factors affecting the attack of rodents in feed storage areas

1. Food Availability: The presence of a readily available food source, such as feedstuff, is a primary factor attracting rodents to storage areas. If feed storage facilities are not adequately protected, rodents will be more likely to enter and establish themselves in search of food.

2. Storage Practices: The way feed is stored can impact rodent activity. Improper storage practices, such as leaving feed bags open or unsealed, using damaged containers, or failing to maintain a clean environment, can make it easier for rodents to access and consume feed. Effective storage practices, including using rodent-proof containers, sealing openings, and maintaining cleanliness, can deter rodent attacks.

3. Structural Integrity: The condition of storage structures plays a role in rodent infestation. If buildings, bins, or silos have cracks, gaps, or other openings, rodents can easily gain entry. Regular inspections and repairs to ensure the integrity of storage structures can help prevent rodent attacks.

4. Sanitation: Poor sanitation practices in and around feed storage areas can attract rodents. Spilled feed, accumulation of debris, and improper waste management create favorable conditions for rodent infestations. Implementing proper sanitation measures, such as promptly cleaning up spills, removing debris, and maintaining a clutter-free environment, can discourage rodent activity.

▪ Control:

To mitigate the effects of rodents on feed storage, it is essential to implement effective pest control measures. This may include employing traps, using rodenticides (Brodifacoum, bromadiolone, cholecalciferol, zinc phosphide) cautiously and responsibly, securing storage structures to prevent rodent entry, practicing good sanitation and hygiene, and monitoring storage areas regularly for signs of rodent activity. It is crucial to follow local regulations and guidelines regarding pest control and the use of rodenticides to ensure the safety of animals, humans, and the environment.

2. Micro-organism

The degradation of feedstuff during storage is significantly influenced by microorganisms. They can result in a number of types of spoiling, including bacterial infection, fermentation, and mould growth. Here are several ways that microorganisms affect how quickly feedstuffs deteriorate:

1. Mould Development: Feed that is stored often develops mould. The environment contains microscopic mould spores, which can contaminate feed during harvest, processing, or storage. The spores germinate and produce visible mould colonies in the presence of favourable conditions including moisture, temperature, and oxygen availability. Mycotoxins, which can injure animals and lower the nutritional content of the feed, are toxic substances that are produced as a result of mould growth. Perhaps the most significant mycotoxins infecting feedstuffs are the aflatoxins, a series of extremely poisonous and cancer-causing compounds generated by *Aspergillus flavus*. Farm animals

consuming polluted feed can transmit the toxin to meat and eggs, increasing the risk to human health. Aflatoxin's toxicity to fish has not been thoroughly studied, however trout's toxicity (oral LD50: 0.5 mg/kg body weight) is equivalent to that of ducklings, which are known to be the most vulnerable animals to aflatoxin poisoning.

Groundnut cakes, maize, sorghum, sunflower, cottonseed cakes, copra, and cassava are among the feed ingredients reported to be infected with *A. flavus*. However, *A. flavus* must exist by itself in a virtually pure culture in order to create aflatoxin. In addition, the fungus only develops the toxin in these crops at moisture levels of 9 to 10%, as opposed to 17 to 18% for the majority of feed grains. Therefore, tropically cultivated feed grains like sorghum and maize also carry a high danger.

2. Bacterial Contamination: When the feed is being harvested or processed, bacteria can contaminate it. Bacterial development is aided by Factors including moisture, temperature, pH, and the presence of nutrients. It is possible for a bacterial infection to result in the generation of toxins such botulinum toxin, which can seriously illness animals. Additionally, bacteria may aid in the breakdown of the feed's proteins, carbs, and lipids, lowering the nutritional value of the feed.

3. Fermentation: In stored feed, microorganisms, notably yeasts and lactic acid bacteria, can start the process of fermentation under specific circumstances. When there is enough moisture, not enough oxygen, and fermentable carbohydrates present, fermentation can take place. This procedure results in the creation of organic acids (such as lactic acid) and alcohol, which lowers feed pH and degrades nutrients. Feed that has been fermented is less palatable, contains fewer nutrients, and could upset an animal's digestive system.

4. Nutrient Loss: Microorganisms are capable of degrading a variety of feed ingredients, which causes nutrient loss. For instance, fungi and bacteria can break down proteins into more basic substances like ammonia, lowering the protein quality of the meal. Additionally, carbohydrates can be fermented or used by microbes, which lowers their energy value. The nutritional value of the meal might also be further compromised by bacteria' utilization or degradation of vitamins and other important elements.

5. Increase in the level of Moisture and heat: Increasing temperatures and moisture content are associated with mould growth in feedstuffs. The first prominent species to become engaged in a feed grain mould infestation is *Aspergillus glaucus*, which has a minimum moisture requirement of 14.5 percent. An increase in temperature that coincides with this initial attack encourages the growth of a second species, *A. candidus*, which pushes the moisture content of the infected grain to 18% or higher. *A. flavus* activity increases and the wholesomeness of the feed grain is completely destroyed at such high moisture levels.

In most cases, severe harm is already done in feed grains when fungus activity is detected. This is because such action occurs inside the storage container, far from the surface, where the temperature gradients it causes quickly vanish. Therefore, temperature sensors should be installed in grain silos to give alerts when problems arise. A large stack of bags "sweating" indicates that the grain being stored has been severely fungus-damaged.

6. Staleness:

Fungi-damaged feeds can develop lumpy textures. Feed grains get discoloured, whereas ruined maize develops a dark brown tint with some kernels that have browned. The grain also has a

distinctive bluish shine. Other characteristics of goods harmed by fungi include staleness or mustiness.

3. Factors Affecting Fungal Growth in Feedstuffs

Factors	
Moisture content	Above 15 %
Relative Humidity	Between 70 and 90%
Temperature	Above 25 degrees Celsius Aspergillus spp. and Penicillium spp. develop at maximum temperatures of 55 C and at least a relative humidity of 65 percent. When relative humidity surpasses 85% and temperatures are higher than 25 C, they are most damaging.
Nutrient Availability	It mostly grows on decomposed nutrients or the simplest forms of nutrients like carbohydrates, proteins, and fats, if available the moulds can proliferate easily.
Oxygen	It takes oxygen for mould to grow. In the feed storage space, stagnant air or inadequate ventilation might foster the formation of mould. In order to stop the growth of mould, proper ventilation is essential.
Cleanliness	Mould spores may be found on objects, machinery, or storage containers. Its contamination and growth risk can be decreased with routine cleaning and disinfection.
Feed Composition	Some feed additives are more likely than others to support the growth of mould. For instance, grains and oilseeds have greater moisture contents and, if not stored properly, might foster the growth of mould. These components might already contain mould spores, and under the appropriate circumstances, they could begin to proliferate.
Storage Duration	The likelihood of mould growth increases with the amount of time feed is kept. Even minute quantities of mould spores in the feed have the potential to grow and spread over time if the right circumstances exist. Mould issues can be reduced by regular monitoring and rotating feed to cut down on storage time.

Control

Because the destructive activities of insects frequently produce conditions favourable to mould, namely increased moisture and temperature and the destruction of the protective hulls of feed grains expose their moist interiors, the prevention of mould contamination of stored feedstuffs depends primarily on the successful control of insect infestation. Mould cannot be eliminated effectively, however effective controls for limiting its growth in complex feeds have been established. The usage of propionate and, more lately, gentian violet are some of these precautions. To prevent the degradation of feedstuff during storage, it is crucial to adopt efficient storage practices, such as appropriate sanitation, moisture control (<15%), temperature management (<20 degree Celsius), RH (<70%), periodic monitoring for rotting symptoms, and short-term storage (2-3 months). The addition of Na and Ca propionate at 0.5-1% in fish feed lessen the growth of microorganisms, preserve the product's quality, and preserve the nutritional integrity of the product.

There are several other chemicals that can be used to eliminate or reduce aflatoxin contamination in feedstuff during storage. One commonly used chemical is ammoniation, which involves treating the feedstuff with ammonia gas. Ammoniation can help reduce aflatoxin levels in feed by breaking down the toxin and rendering it less harmful. Another approach is to use binders or adsorbents such as activated charcoal, bentonite clay, or hydrated sodium calcium aluminosilicate (HSCAS). These materials can bind to aflatoxins, preventing them from being absorbed by animals during digestion. Additionally, certain organic acids like propionic acid, acetic acid, and citric acid have shown effectiveness in reducing aflatoxin levels in feed. These acids can inhibit the growth of aflatoxin-producing fungi and help to degrade or detoxify aflatoxins.

Deterioration due to physical factors

During the storage of feedstuff, various physical factors can contribute to its deterioration. These factors include:

- 1. Moisture:** Excessive moisture can lead to the growth of molds, bacteria, and fungi in feedstuff. These microorganisms can degrade the nutritional value of the feed and produce mycotoxins, which are harmful to animals. Moisture can also cause clumping, caking, and spoilage of the feed.
- 2. Temperature:** High temperatures can accelerate the growth of microorganisms and promote chemical reactions, leading to the breakdown of nutrients in feedstuff. Heat can also cause the Maillard reaction, which reduces protein quality and digestibility. Fluctuating temperatures can result in moisture condensation, further promoting mold growth and spoilage.
- 3. Relative Humidity:** High RH enhances moisture absorption, mold growth, nutrient loss, caking, and insect infestation that causes huge deterioration of feed stuffs during storage.
- 4. Oxygen:** Exposure to oxygen can lead to oxidation of fats and oils present in feedstuff, causing rancidity. Oxidation reduces the nutritional value of feed and impairs its palatability. It can also lead to the formation of harmful compounds, such as peroxides, that can be toxic to animals.
- 5. Light:** Exposure to sunlight or artificial light can cause photooxidation of feed components, particularly vitamins, and pigments. This leads to a loss of nutrient quality and color fading. Protecting feedstuff from direct light can help minimize these effects.

Control

To minimize the deterioration of feedstuff due to these physical factors, it is important to follow good storage practices. This includes storing feedstuff in clean, dry, and well-ventilated areas with controlled temperature and humidity levels. The maximum recommended moisture level in general for fish feed is to keep below 15%, specifically for extruded feeds, it is 12%. Feed manufacturers always keep the moisture level at around or below 10%, which keeps the feed protected during storage. The optimum recommended temperature level is to keep below 20 degrees Celsius and RH below 70%, which renders the deterioration. Using appropriate packaging materials and sealing feed containers tightly can help prevent moisture and oxygen ingress. Regular inspection, rotation of stock, and implementation of pest control measures are also crucial for maintaining feed quality during storage.

Deterioration due to chemical factors

During storage, feedstuff can undergo various chemical changes that can lead to its deterioration. These changes can affect the nutritional value, palatability, and overall quality of the feed. Some common chemical changes that occur during feed storage include:

1. Oxidation: Fats and oils in feedstock are prone to oxidation, especially when they are exposed to air. Oxidation causes the meal to lose some of its nutritional value and develop rancid flavours and unpleasant odours. Additionally, it may lead to the creation of dangerous substances like free radicals. Foods that contain highly unsaturated lipids, including fish meal and rice bran, are particularly prone to oxidation. The first step in the oxidation of lipids involves auto-oxidation, which is the direct reaction of lipids with oxygen molecules to produce hydroperoxides. Then, if more oxidation occurs or if the hydroperoxides are dehydrated, further reactions occur, producing diperoxides or ketoglycerides, respectively.

Hydroperoxides split into compounds with carbonyl and hydroxy groups, which can then react with one another to produce additional products. Epoxides and hydroxy glycerides are produced when carbon-carbon double bonds in other molecules are oxidised. These rancidity-related byproducts of secondary oxidation of lipids include hazardous chemicals that are usually linked to "off flavour." Additionally, the epsilon-amino group of lysine can react with carbonyl groups created by the fission of aldehydic hydroperoxides, decreasing the protein's nutritional value.

The following are the main causes of lipid oxidation in foods that have been stored:

- a. the presence of lipoxidase and maybe other enzymes
- b. hematin is important in the preservation of fish and meat meals
- c. peroxides
- d. The photolysis of peroxides - ultraviolet light.
- e. high temperatures in general; lipids break down more quickly at higher storage temperatures.
- f. catalyzed by trace metal, including iron, copper, cobalt, and zinc, speed up the oxidation of lipids. While zinc causes the breakdown of hydroperoxide into free radicals, iron and copper accomplish this by direct electron transfer in redox processes.

The addition of substances referred to as anti-oxidants can prevent lipid oxidation. Ethoxyquin and butylated hydroxytoluene are two widely used feed antioxidants that bind free radicals produced during oxidative reactions. Unless the kernels are destroyed during storage, cereal grains contain significant amounts of natural antioxidants (such as tocopherols) that significantly increase the stability of their lipid contents.

2. Maillard reaction: This reaction occurs between amino acids and reducing sugars present in the feed. It is responsible for the browning of feedstuff and can result in the formation of undesirable flavors and reduced protein digestibility.

3. Hydrolysis: Hydrolytic reactions involve the breakdown of complex molecules in the feed into simpler components due to the presence of water. Enzymes naturally present in the feed or microbial activity can catalyze these reactions. Hydrolysis can lead to the degradation of proteins, carbohydrates, and other nutrients, reducing their availability to animals.

4. Fermentation: When moisture content and temperature conditions are favorable, feedstuff can undergo fermentation. This process involves the activity of microorganisms, such as bacteria and fungi, which can produce organic acids, alcohols, and gases. Fermentation can lead to a decrease in feed pH, nutrient losses, changes in taste and smell, and the growth of harmful toxins, such as mycotoxins.

5. Condensation and polymerization: Some feed components, such as sugars and amino acids, can undergo condensation and polymerization reactions during storage. These reactions can result in the formation of non-digestible compounds, reducing the nutritional value of the feed.

Control

To minimize the deterioration of feedstuff due to these chemical changes, it is important to implement proper storage practices. This includes storing feed in dry, cool, and well-ventilated areas, protecting it from sunlight and moisture, and using appropriate packaging materials. Additionally, regular quality checks, such as sensory evaluation, nutrient analysis, and microbiological testing, can help detect any signs of deterioration and ensure the feed's safety and quality.

Storing Feedstuffs

Some weight loss of feedstuffs during storage is unavoidable. Thus ingredients should be stored for as short a period as possible and compounded feeds used quickly, especially in tropical conditions. The method of storage depends on the type of ingredient.

Dry Ingredients

When storing dry feed, such as grains, it's important to follow proper storage practices to maintain its quality and prevent spoilage. Here are some guidelines for storing dry feed:

- 1. Clean and dry storage area:** Ensure that the storage area is clean, dry, and free from any contaminants. Remove any old feed residue or debris before storing new feed.
- 2. Pest control:** Implement measures to prevent pests such as rodents or insects from accessing the feed. This can include using rodent-proof containers, sealing any gaps or cracks in the storage area, and regularly inspecting for signs of infestation.
- 3. Temperature and humidity control:** Dry feed should be stored in a cool, dry place. High humidity can lead to moisture absorption and mold growth, while excessive heat can accelerate spoilage. Aim for a storage area with stable temperature and humidity levels.
- 4. Proper containers:** Use appropriate containers for storing dry feed, such as airtight bins, plastic or metal drums, or silos. These containers should be sturdy, durable, and resistant to moisture and pests. Make sure they have tight-fitting lids or covers to prevent exposure to air and humidity.
- 5. Rotation and first-in, first-out (FIFO):** Practice proper inventory management by implementing a FIFO system. This means using the oldest feed first and rotating your stock to avoid having feed sitting for extended periods. This helps ensure that feed is used before it becomes stale or loses its nutritional value.
- 6. Avoid direct sunlight:** Store dry feed away from direct sunlight or strong UV radiation, as it can accelerate the degradation process and reduce the feed's quality.
- 7. Labeling and record-keeping:** Clearly label your feed containers with the type of feed, date of purchase or production, and any other relevant information. Maintain a record of your inventory to track usage and replenishment.
- 8. Regular inspections:** Periodically inspect your stored feed for signs of spoilage, such as mold, unusual odors, or pests. Remove any damaged or spoiled feed immediately to prevent contamination of the rest of the stock.

Dry Compounded Feeds

These should be handled similarly to dry ingredients, although they shouldn't be kept in storage for a very long time. Individual ingredients are less likely to be damaged than mixed diets. This is a result

of the interactions between various components as well as cross-contamination with fungi and insects. Because many of the harmful components will have been eliminated, mixed feeds that have had a heat treatment during manufacture, such as steam pelleting, keep better than other mixtures.

Protein Sources

- a. Low-fat (<1%), dry (12% moisture) protein sources may be kept indefinitely. However, they should be labeled with an acquisition date.
- b. Meals with fat, usually >2% have a limited shelf life that may be extended to about 6 months if an appropriate antioxidant has been added. These meals should be stored in a cool location (ideally <77°F).
- c. Whole seeds (soybeans, cottonseed, sunflower, etc.) will be kept in a cool location for at least one year.

Moist/Wet Ingredients and Compounds

When using these materials, such as 'trash' fish, they must either be used fresh (they can be iced down for up to 12 hours while stocks are being pulled from a delivery for use) or maintained frozen. If you don't already have a plate freezer (for example, to freeze your collected aquaculture product), freezing should be outsourced to a specialist. Proper freezing of large amounts of wet materials like these requires one. This kind of ingredient can be frozen and kept in a cold storage facility. The cold store's temperature should not rise above -20°C, ideally below -30°C.

To prevent the product temperature from rising too much, rules must be set to reduce the amount of time and openings that the cold store door experiences. Small quantities of moist materials can be frozen in a cold store if access to plate freezing facilities run by experts is not available. However, only in extremely small amounts. The material must be distributed in thin (1 inch) layers, and the store cannot be overrun with a large volume of unfrozen items. It will take many days until waste fish in a huge drum or bag is totally frozen in a cold store; in the meantime, the feed will be rapidly deteriorating. It will take many days for trash fish stored in a large drum or bag to completely freeze in the cold store; during that time, the feed will rapidly deteriorate. Use moist compound meals within 2-3 hours of manufacture on the day. Use only dry components free from ammonia odour.

Vitamins

Because vitamins and vitamin blends are such expensive components, they require cautious handling. Storage space is typically not a limiting problem for them because their volume is typically tiny due to their low inclusion rate. Before storage, vitamins shouldn't be combined with minerals. Vitamins and vitamin premixes are to be stored in the original packaging from the manufacturer or in airtight, light-proof containers. Keep them away from warm, sunny rooms. They should be kept as cool as possible, preferably in an air-conditioned space. At the very least once every six months, stocks should be changed.

Lipids

Keep in airtight containers, ideally made of plastic, in a cool, dark location. Make sure that when they were made, antioxidants were included.

Storage period

	Tropical Zone	Temperate Zone
Ground Ingredients	1-2 months	3 months
Whole Grain and Oilcakes	3-4 months	5-6 months
Compounded Dry Feeds	1-2 months	1-2 months

	Tropical Zone	Temperate Zone
Vitamin Mixes (kept cool etc.)	6 months	6 months
Wet Ingredients	2-3 hours	2-3 hours
Frozen Materials	2-3 months	2-3 months

Summary

The lion's share of the production cost is contributed by feed if this very valuable commodity is kept in adverse conditions, it will become susceptible to deterioration - extra pressure on the fish producers. Appropriate storage practices, such as appropriate sanitation, moisture control (<15%), temp. management, periodic monitoring, and short-term storage (2-3 months), keep feedstuffs safe. The maximum recommended moisture level in general for fish feed is to keep below 15%, specifically for extruded feeds, it is 12%. The optimum recommended temperature level is to keep below 20 degrees Celsius and RH below 70%, which renders the deterioration.

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FEMALE AGRICULTURAL WORKERS: THEIR ECONOMIC IMPACT AND POLICY IMPERATIVES

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Introduction

Agriculture is the backbone of rural livelihoods, and within it, women form the invisible workforce. Across developing countries, especially in South Asia and Sub-Saharan Africa, women contribute significantly to agricultural production, post-harvest processing, and market activities. Yet, their contributions remain undervalued, under reported, and unsupported by policies.

“If women had the same access to productive resources as men, they could increase yields on their farms by 20–30%” — *FAO, 2011*

This article explores the economic impact of female agricultural workers and highlights the need for gender-sensitive agricultural policies.

Role of Women in Agriculture

1. Nature of Work

Women in agriculture perform a wide range of tasks including:

- Sowing, weeding, harvesting
- Post-harvest processing
- Animal husbandry
- Seed preservation
- Marketing of small-scale produce

In India, women contribute over 60% of labor in the agriculture sector (*NSSO, 2019*).

2. Sectoral Presence

- Crop production (rice, wheat, millet)
- Horticulture and floriculture
- Dairy and poultry
- Agro-processing industries

Economic Contributions

1. Labor Force Participation

- Women constitute nearly 43% of the agricultural labor force in developing countries (*World Bank, 2021*).
- In India, about 75% of rural women are involved in agriculture either as laborers or farmers (*Ministry of Agriculture, GoI, 2022*).

2. Unpaid and Invisible Work

Despite their extensive labor, most women do not own land or receive wages. Their unpaid work is not counted in GDP, creating a gender data gap.

McKinsey Global Institute (2015): Closing the gender gap in labor force could add \$12 trillion to global GDP by 2025.

3. Contribution to Food Security

Women's role in food production and processing directly supports household nutrition and national food security.

Gender-Based Disparities

1. Land Ownership : Only 13% of agricultural landholders in India are women (*Agricultural Census, 2015-16*). Landlessness reduces women's access to credit and government schemes.

2. Wage Gap : Women earn 60–70% of what male agricultural laborers earn, despite longer working hours.

3. Access to Inputs and Technology

Women have limited access to:

- Improved seeds and tools
- Irrigation
- Credit and crop insurance
- Training and extension services

FAO (2020): Women receive only 5% of agricultural extension services worldwide.

Structural Challenges

1. Social Norms and Patriarchy : Traditional norms limit women's mobility, control over income, and decision-making power.

2. Time Poverty : Women juggle multiple roles—farmers, caregivers, food providers—resulting in long, unpaid workdays.

3. Legal and Institutional Barriers : Inheritance laws, lack of land titles, and male-centric program designs exclude women from formal agriculture systems.

Impact of Climate Change and Technology

Women are disproportionately vulnerable to:

- Climate variability
- Water scarcity
- Soil degradation

Yet, they are underrepresented in:

- Climate-smart training
- Agri-tech platforms
- Government relief schemes

UN Women (2021): Women are more likely to suffer economic losses from climate-induced agricultural shocks.

Case Studies

1. India: Self-Help Groups and Women Farmers

The Mahila Kisan Sashaktikaran Pariyojana (MKSP) supports women in organic farming, livestock management, and value addition. States like Kerala and Andhra Pradesh show positive income and empowerment outcomes.

2. Africa: Women in Agribusiness

Programs like AWAN-Afrika promote women entrepreneurs in agriculture. This has led to:

- Job creation
- Increase in local market access
- Gender sensitization among suppliers

Economic Empowerment through Inclusion

1. Access to Land and Resources : Secure land rights boost women's productivity, investment, and participation in formal markets.

2 Credit and Insurance : Tailored microfinance, SHG-bank linkages, and low-premium insurance schemes increase economic resilience.

3. Skill Development and Extension : Women-centric extension services and digital training improve productivity and adoption of innovations.

Example: Digital Green (India) uses community videos to train women farmers, increasing adoption of best practices by 30%.

Policy Imperatives

1. Gender-Inclusive Agricultural Policies

- Include women in scheme design and governance (e.g., FPOs, co-operatives)
- Disaggregate data by gender in agricultural surveys

2. Strengthen Legal Frameworks

- Enforce equal inheritance rights
- Simplify land titling and joint ownership processes

3. Promote Female Farmer Recognition

- Recognize women as “farmers” (not just laborers)
- Provide ID cards for direct benefit transfer

4. Social Infrastructure

- Childcare centers
- Clean water and sanitation
- Safe transportation

These improve women's mobility and participation in markets.

Conclusion

Women are the backbone of agriculture, yet they remain economically marginalized and institutionally invisible. Unlocking their potential requires a combination of targeted investments, land rights, gender-sensitive technology, and inclusive policies. If empowered, women agricultural workers can transform rural economies, enhance food security, and reduce poverty at scale.

“There is no sustainable development without gender equality in agriculture.” — *UN SDG Report, 2023*

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SHIITAKE- THE IMMUNE BOOSTER MUSHROOM

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Abstract

Lentinula edodes (Shiitake) is a widely recognized edible and medicinal mushroom, often revered as the “elixir of life” in traditional Asian medicine. It contains an array of bioactive compounds including lentinan, eritadenine, polysaccharides, and phenolic acids, which exhibit antibacterial, antioxidant, anti-inflammatory, immunomodulatory, and anticancer properties. These compounds contribute to its potential role in preventing and managing conditions such as cancer, hypertension, hyperlipidemia, and infectious diseases. Due its rich nutritional profile and broad therapeutic spectrum, Shiitake is increasingly recognized as one of the most valuable functional foods. This article explores its immune-stimulating capabilities and therapeutic significance while also addressing associated precautions and potential side effects.

Keywords: Shiitake, *Lentinula edodes*, Medicinal Mushroom, Immune Modulation, Functional Food

Introduction

Lentinula edodes (Shiitake) is a wood-decomposing basidiomycete fungus traditionally cultivated on hardwood logs and more recently on synthetic substrates such as sawdust. Native to East Asia, it thrives in warm, humid forests, particularly on decaying hardwoods like oak, chestnut, and beech. Known as “Xiang gu” in China and deriving its Japanese name from “shii” (oak) and “take” (mushroom), Shiitake has a long history of use in traditional medicine.

Scientific interest in *L. edodes* surged in the late 20th century with the discovery of its potent bioactive constituents such as lentinan and eritadenine, which offer cholesterol-lowering, immunomodulatory, antioxidant, antimicrobial, and anticancer properties. It is now the second most commonly cultivated mushroom globally, after *Agaricus bisporus*, with major production centers in China, Japan, Korea, the United States, and parts of India including Himachal Pradesh and Uttarakhand.

Shiitake mushrooms possess an impressive nutritional profile, rich in essential amino acids, β -glucans, phenolics, sterols (ergosterol), lipids, dietary fiber, and vital vitamins and minerals. Among these, lentinan—a β -(1 $\rightarrow$ 3)-glucan with β -(1 $\rightarrow$ 6) branches—has been extensively studied for its immunoenhancing and anticancer effects (Rahman et al.,2012).

Bioactive Compounds of Shiitake Mushroom (Ahmad et al.,2023)

Compound	Biological Function
Lentinan (β -glucan)	Immunostimulant; antitumor activity
Eritadenine	Lowers serum cholesterol; supports cardiovascular health

Compound	Biological Function
Ergosterol	Precursor to Vitamin D ₂ ; aids calcium absorption
Polysaccharides	Antiviral; immunomodulatory effects
Phenolic acids	Antioxidant; anti-inflammatory actions
B-complex vitamins	Support metabolism and nervous system function
Essential minerals (Zn, Cu, Se)	Cofactors for immune and antioxidant enzymes
Lavostatin	Inhibits HMG-CoA reductase; reduces cholesterol synthesis
Lenthionine	Antibacterial and antifungal properties
LEM, LAP	Antitumor activity; investigated in Hepatitis B treatment
EP3	Antiviral activity against herpes simplex virus and HIV

Immune-Boosting Properties of Shiitake

1. Immunomodulation

- Lentinan activates macrophages, dendritic cells, natural killer (NK) cells, and T-lymphocytes.
- Stimulates cytokine secretion such as IL-1, IL-6, and IFN- γ , enhancing innate and adaptive immunity.
- Strengthens host defense mechanisms against pathogens.

2. Antiviral and Antimicrobial Activity

- Exhibits inhibitory effects on viruses including influenza, HIV, and hepatitis B.
- Enhances viral resistance and disrupts viral replication.
- Shows antibacterial activity against *Staphylococcus aureus*, *E. coli*, and *Candida albicans*.

3. Anti-Tumor and Anticancer Effects

- Clinically used as an adjuvant in cancer therapy (e.g., gastric and colorectal cancers) in Japan.
- Suppresses tumor progression by enhancing immune surveillance and inhibiting angiogenesis.

4. Cardiovascular Support

- Eritadenine aids in the excretion of cholesterol and modulates liver lipid metabolism.
- Helps lower low-density lipoprotein (LDL) cholesterol levels and supports cardiovascular health.

5. Antioxidant and Anti-inflammatory Properties

- Rich in phenolic compounds, ergothioneine, and superoxide dismutase (SOD) that neutralize oxidative stress.
- Reduces inflammatory markers such as C-reactive protein (CRP) and tumor necrosis factor- α (TNF- α).

6. Support for Skin, Liver, and Digestive Health

- Promotes collagen synthesis and skin elasticity.
- Protects hepatocytes from oxidative and toxic damage.
- Aids gut microbiome balance and improves digestion.

Side Effects of Shiitake Mushroom

Though generally considered safe, certain adverse effects have been reported:

- **Shiitake Dermatitis:** A rare rash resulting from raw or undercooked consumption due to lentinan.

- **Gastrointestinal Upset:** Bloating, nausea, or diarrhoea in sensitive individuals.
- **Allergic Reactions:** Possible symptoms include hives, rashes, and itching.
- **Photosensitivity:** Rare light sensitivity triggered by mushroom constituents.
- **Drug Interactions:** May affect individuals on anticoagulants or immunosuppressants.

Precautions

- Always consume Shiitake cooked to deactivate harmful compounds.
- Start with small portions, especially for first-time consumers.
- Avoid raw consumption entirely.
- Consult a healthcare provider before use in pregnancy, lactation, or concurrent medication.

Conclusion

Shiitake mushroom is a potent natural immune enhancer, offering a wide array of health benefits. With its abundance of biologically active compounds and minimal side effects when consumed properly, it stands out as a functional food of high therapeutic value. Incorporating Shiitake into daily diets can help strengthen immune defense, improve cardiovascular and digestive health, and reduce inflammation. When used with caution and proper guidance, it holds promise as a sustainable, natural food for enhancing overall wellness.

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FISH HYBRIDIZATION: CREATING BETTER FISH THROUGH SCIENCE

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Abstract

Hybridization is the process of breeding the two different parent individuals to produce a new product with improved qualities. And they are defined as Hybrids. Here this article revises about the hybridization in different fishes like silver carp consumes only phytoplankton and big head carp consumes only zooplankton, the hybrid will have the ability to consume both the phytoplankton and zooplankton, which produces 100% males by crossing two different tilapia. There are three major types of hybridization i.e., Interspecific, Intergeneric and intraspecific hybridization when hybridization is done between the same genera, different genera and same species with different strains respectively. In aquaculture by producing the hybrids by this hybridization process will improve the productivity, and survival and the diseases caused due to environmental conditions.

Key words: Hybridization, Heterosis, Hybrids, Interspecific, Intraspecific, Intergeneric, Sterility.

Introduction

The process of combining the haploid (n) genome of two different parent species belongs to same genera or different genera or sometimes same species with different strains and producing the hybrids is known as the Hybridization, the produced offspring's were termed as Hybrids. Hybridization facilitates quick genetic improvement. Fish hybrids are generally tend to be intermediate in phenotypic characters pertaining to the parents but may show advantageous qualities like better growth rate, better food conversion rate, higher survival rate, diseases resistance against unfavorable environmental conditions, higher slaughtering value, quick genetic improvement etc.

Types of hybridization

There are three types of hybridization, they are:

1. Interspecific hybridization
2. Intergeneric hybridization
3. Intraspecific hybridization

1. Interspecific hybridization: The hybridization occurs between two different species with same genus is known interspecific hybridization. This type of hybridization often results in fertile hybrids that display traits from both parents.

Eg : *Labeo calbasu* × *L. rohitha* hybrid
L. beta × *L. calbasu* hybrid.

2. Intergeneric hybridization: The hybridization of two individuals with different genera of fish. This type of hybridization often results in sterile due to genetic incomparability.

Eg : *Labeo rohitha* × *Catla catla* hybrid
Catla catla × *L. rohitha* hybrid.

3. Intraspecific hybridization: It includes the crossing over between the same species with different strains within them is termed as Intraspecific hybridization.

Eg : Different strains of African catfish (*Clarias gariepinus*).

The Russians are the pioneers in the field of hybridization in fishes. Hybridization was mainly limited to trout, sunfish, tilapia and recently also extended to catfishes and some of the salmon fishes.

1. Combining traits of different species:

Eg : silver carp × big head carp hybrid

The main aim is to produce a fish capable of utilising phytoplankton (like silver carp) and the zooplankton like (big head carp). The pores of filtering apparatus of hybrid were intermediate in size between the two parent species and the hybrid was able to filter both kinds of plankton. But the hybrid could not efficiently filter micro blue green algae that frequently forms blooms in the pond.



Fig :1: Crossing of different species: silver carp × big head carp and their hybrid

2. Sterility

Eg: Grass carp × Big head carp hybrid

Grass carp is known to control higher vegetation in aquatic system. In some regions their introduction is not permitted as their uncontrolled reproduction may totally eradicate aquatic plants from the culture system. Grass carp × big head carp hybrids were mostly sterile triploids, and moderate grass grazing capacity. These hybrids were suitable for controlling aquatic vegetation through moderate grazing of aquatic vegetation/plants.

3. Producing monosex broods

Eg : Hybrids between different tilapia Species

In tilapia hybridization, the hybrids produced were all males. For example, crossing over the female *Oreochromis niloticus* with male *O. hornorum* result in the production of 100% males. Similarly crossing between female *O. mossambicus*, with male *O. hornorum* and male *O. mossambicus*

crossed with female *O. niloticus* also resulted in the production of all males. This will resolved the difficulties which were faced in massive spawning of tilapia in the fish tanks or the ponds.

Female	Male	Sex chromosome		Offsprings
		Female	Male	
<i>O.mossambicus</i>	<i>O.niloticus</i>	XX	XY	100% males
<i>O.niloticus</i>	<i>O.hornorum</i>	XX	ZZ	100% males
<i>O.mossambicus</i>	<i>O.hornorum</i>	XX	ZZ	100% males
<i>O.niloticus</i>	<i>O.mossambicus</i>	XX	XY	100% males

4. Heterosis/ Hybrid vigor

The process of hybridization which leads to the production of hybrids with superior qualities than that of both the parents . It is also termed as Hybrid vigor. Heterosis is expected when geographically remote varieties and subspecies are crossed over each other. **Eg: female channel catfish × male blue catfish**, leads to improve the productivity trait 10-18% also improved the FCR and egg production.

5. Hybridization in Indian major carps

Among different hybrids, catla - calbasu hybrid grows faster than calbasu, with a smaller head than that of catla & greater girth than calbasu.

Off all the hybrids produced rohu – catla hybrid was very promising in the growth, food intake, feeding habits, viability & higher flesh content. Head is smaller than catla. Flesh content is more when compared to both the parents. Growth of hybrids is faster than that of rohu but smaller than catla.

Based on the age of first maturity eg; **Mrigal × common carp**, where Mrigal will mature within 12 months and common carp will mature within 6 months but the hybrid produced by this crossing over will be sterile and to be triploid.

Based on the flesh content where rohu with 48% of flesh is crossed with catla which contains 44% of flesh, the hybrid formed will have about 54% of flesh content which is higher than that of both the parents.

Triploid hybrids will be produced when the common carp is crossed with the IMC males.

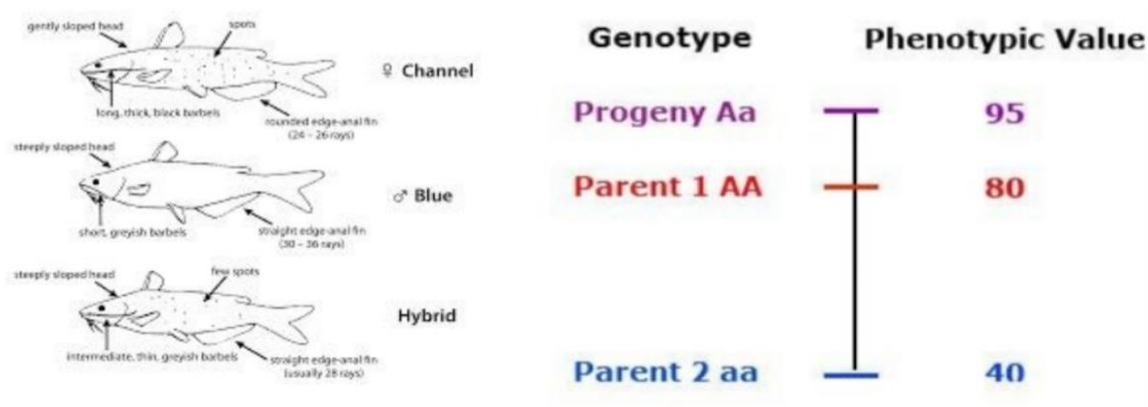


Fig-2 : Heterosis : female channel catfish × male blue catfish hybrid and hybrid vigor

6. Hybridization between two fresh water catfishes

When two freshwater catfishes were crossed will produce the true hybrids. For example., *Heteroneustes fossilis* × *Clarius batrachus*. Where *H.fossilis* with (2n=56) is crossed with *C.batrachus* (2n=50) then the hybrid produced is *C. batrachus* externally, but molecular analysis revealed that they were true hybrids (2n= 53). The valuable traits of aquaculture importance of these hybrids are under investigation.

7. Hybridization of penaeid shrimps

Interspecific hybridization of the following species will produce the hybrids with faster growth rate than both of their parents. They were eg: *Penaieus setiferus* × *P. stylirostrus*, *P. setiferus* × *P. schmitti*, *P. monodon* × *P. penicillatus* other interspecific hybrids produced exhibited low hatchability, lack of hybrid vigor & hence the feasibility of immediate commercial application is not bright.

Conclusion

Hybridization in fishes is a powerful tool that helps improve fish farming. By combining the best traits from different species or strains, scientists can produce fish that grow faster, resist disease, and provide better yields — ultimately helping both farmers and consumers.

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FLOOD-PROOFING ODISHA : ENGINEERING SOLUTIONS TO SAVE FARMLANDS

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Abstract

Odisha's 33,400 sq km of coastal farmlands face annual floods from rivers like Mahanadi, causing ₹1,200 crore in damages in 2023. Engineering solutions, including 7,434 km of embankments and 8,987 km of drainage systems, protect 1.9 lakh hectares. This article highlights flood control infrastructure in Jagatsinghpur and Puri, updated with 2025 Rural Infrastructure Development Fund (RIDF) data. Embankments, spurs, and drainage works save crops, while farmer-friendly tips enhance resilience against erratic monsoons.

Keywords: Flood control, embankments, drainage, Odisha, agriculture

Introduction

Odisha's coastal plains battle annual floods, submerging farmlands like Ramesh Behera's in Jagatsinghpur, who lost ₹2 lakh in 2023 (OSDMA, 2025). With 33,400 sq km flood-prone, rivers like Mahanadi and Brahmani threaten 10% of the state (CWC, 2020). Yet, 7,434 km of embankments and 8,987 km of drainage systems shield 1.9 lakh hectares (DoWR, 2025). This feature explores Odisha's flood-proofing infrastructure and strategies to safeguard agriculture.

Flood Challenges in Odisha

Floods, where dry land is submerged by rainfall or river overflow, range from flash events to months-long inundation (UNISDR, 2015). In Odisha, causes include:

- **Heavy Rainfall:** Jagatsinghpur's 2023 monsoon hit 1,446 mm against 1,119 mm normal (Table 1).
- **Poor Drainage:** Flat coasts and silted rivers delay runoff, affecting 2.17 lakh hectares (DoWR, 2020).
- **Embankment Breaches:** The 2001 Mahanadi flood inundated 1.5 lakh hectares (OSDMA, 2020).

Jagatsinghpur, flooded nearly yearly since 1800, saw ₹300 crore in 2023 agricultural losses (Table 2; OSDMA, 2025).

Table 1: Southwest Monsoon in Jagatsinghpur (2001–2023)

Month	Normal (mm)	Actual Mean (mm)	Std. Deviation
June	222.30	163.47	90.16
July	351.80	310.26	138.55
August	315.80	383.90	158.08
September	229.20	276.06	120.06
Total	1119.10	1133.69	233.07

Source: District Emergency Office, Jagatsinghpur, 2023; OSDMA, 2025

Table 2: Flood Frequency in Jagatsinghpur (1800–2023)

Period	Flood Years
1800–1850	1834, 1845, 1846, 1848
1851–1900	1851–1857, 1862, 1866, 1868, 1872, 1874, 1877, 1879–1881, 1885, 1890, 1892–1896, 1900
1901–1930	1907–1908, 1911, 1913, 1920, 1926–1930
1931–1960	1933, 1937, 1939, 1943–1944, 1947, 1955–1956
1961–1992	1961–1962, 1972–1975, 1977–1980, 1983–1986, 1990–1992
2001–2023	2001, 2003, 2011, 2020, 2023

Source: Government of Odisha, 2003; OSDMA, 2025

Engineering Feats: Embankments and Spurs

Odisha's 7,434 km of embankments, including 4,021 km in the Mahanadi basin, and 1,952 spurs protect 1.9 lakh hectares (DoWR, 2025). Key projects include:

- **Padmabati Embankment:** 2024 slope protection works safeguard 10,000 hectares in Cuttack (DoWR, 2025).
- **Gomu Sluice:** Regulates Birupa river flow, aiding 5,000 Kendrapara farmers (OSDMA, 2025).
- **RIDF Projects:** NABARD's ₹1,200 crore since 2004, with ₹150 crore in 2024–25 for 50 km of new embankments, protects 5.5 lakh hectares (NABARD, 2025;).



Figure 1: Slope Protection on Mahanadi Embankment at Padmabati, 2024

Description: Stone packing and geotextile layers prevent erosion. Source: DoWR, 2025

Drainage Systems: Reclaiming Waterlogged Lands

Flat coastal terrain causes waterlogging in 2.17 lakh hectares (DoWR, 2020). Odisha's 8,987 km drainage network reclaims 1.9 lakh hectares, with:

- **Doab-I (Mahanadi-Kathajodi-Devi):** 1,113 km drains protect 20,500 hectares (DoWR, 2025).
- **Gudiakhal Sluice in Puri:** Under construction in 2025, prevents waterlogging in 3,000 hectares (OSDMA, 2025).
- **Drainage Improvement Programme:** Restored 50,000 hectares in Jagatsinghpur by 2024, boosting rice yields by 20% (OSDMA, 2025).



Figure 2: Gudiakhal Sluice in Puri, 2025

Description: Concrete sluice with steel gates combats waterlogging. Source: DoWR, 2025

Impacts on Agriculture

Floods cut Jagatsinghpur's 2023 rice yields by 15% (OSDMA, 2025). From 1981–2004, autumn rice area fell 1.5% yearly. Losses peaked at 5.8% of GSDP in 1982 (UNISDR, 2015). Infrastructure has:

- Boosted summer rice yields by 1.2% annually in Doab-V (DoWR, 2023).
- Saved 30,000 hectares in Puri in 2020, limiting losses to ₹100 crore (OSDMA, 2020).
- Stabilized incomes for 1.2 lakh farmers in 2024 (NABARD, 2025;).

Farmer-Friendly Practices

Farmers can:

- Avoid wet soil operations.
- Use raised beds for pulses.
- Apply cover crops for soil health.
- Join PMFBY, disbursing ₹500 crore in 2024 (OSDMA, 2023).

Conclusion

Odisha's 7,434 km embankments and 8,987 km drainage systems protect 1.9 lakh hectares from floods. RIDF projects like Gudiakhal sluice boosted yields by 20% in 2024. Farmers should use raised beds and insurance; policymakers must invest ₹2,000 crore by 2030 for 80% drainage coverage. Odisha's model inspires flood-resilient farming.

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FOOD INSECURITY : TYPES, IMPORTANCE, CAUSES, CONSEQUENCES AND REMEDIES

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Introduction

Food is an essential human need, yet millions globally face the ongoing challenge of food insecurity, a serious problem that threatens health, development, and overall well-being. Food insecurity refers to the lack of reliable access to enough nutritious food for maintaining a healthy and active life (FAO,2006). In this article, we will discuss the various types of food insecurity, its significance, root causes, impacts, and possible solutions to address this critical global issue.

Types of Food Insecurity

1. **Chronic Food Insecurity:** This occurs when there is a prolonged and persistent lack of access to adequate food, often due to poverty, low income, or insufficient resources, leading to malnutrition and long-term health problems.
2. **Seasonal Food Insecurity:** This type of insecurity is experienced during certain times of the year, often due to agricultural cycles, such as crop failures or seasonal employment changes (UFBPC,2024).
3. **Acute Food Insecurity:** Characterized by a sudden and severe lack of food access, acute food insecurity typically arises from emergencies like conflicts, natural disasters, or economic collapses, and can lead to hunger or even famine (Pangaribowa *et al.*, 2015).
4. **Hidden Hunger:** This occurs when individuals consume enough calories but lack essential nutrients, such as vitamins and minerals, resulting in malnutrition and health issues.

The Importance of Addressing Food Insecurity

Food insecurity has significant impacts at multiple levels:

1. **Health and Well-being:** Lack of access to nutritious food can lead to malnutrition, stunting growth, weakening immune systems, and making individuals more vulnerable to diseases.
2. **Economic Development:** Food insecurity limits economic growth, as hunger and malnutrition impair cognitive development and reduce individuals' capacity to work or pursue education.
3. **Social Stability:** Food insecurity can drive social unrest, potentially leading to conflicts and forced migrations, underscoring its importance for maintaining societal stability.

Causes of Food Insecurity

1. **Poverty:** One of the primary causes of food insecurity is poverty, which limits people's ability to afford nutritious food.

2. **Climate Change:** Extreme weather events and prolonged droughts can disrupt food production, reducing availability and increasing vulnerability.
3. **Conflict and Instability:** Wars and civil unrest frequently disrupt food supply chains, displace populations, and exacerbate acute food insecurity.
4. **Economic Factors:** Job losses, income inequality, and economic downturns can severely limit access to sufficient food.
5. **Inadequate Infrastructure:** Poor transportation and market systems can prevent the efficient distribution of food, further compounding the problem.

Consequences of Food Insecurity

1. **Malnutrition:** One of the most direct outcomes of food insecurity is malnutrition, which can be particularly harmful to children and can lead to long-term health complications.
2. **Health Problems:** Insecure access to food can lead to a host of health issues, such as obesity, diabetes, and cardiovascular diseases.
3. **Educational Challenges:** Malnutrition negatively affects cognitive development, which can reduce school attendance and academic performance.
4. **Economic Strain:** Food insecurity can reduce productivity and increase healthcare costs, placing a burden on national economies.
5. **Social Unrest:** Severe cases of food insecurity may contribute to political instability and civil unrest.

Solutions for Addressing Food Insecurity

1. **Invest in Agriculture:** Supporting small-scale farmers, improving agricultural practices, and boosting crop yields are key strategies for ensuring greater food availability.
2. **Social Safety Programs:** Programs such as food assistance can protect vulnerable populations from food shortages during crises.
3. **Education:** Promoting nutrition education helps individuals make better food choices and reduces hidden hunger.
4. **Empower Women:** Enhancing women's roles in agriculture and decision-making can significantly improve food security, as women are often central to food production and family nutrition.
5. **Address Climate Change:** Addressing climate change through mitigation and adaptation efforts is crucial for ensuring long-term food security.
6. **Conflict Resolution:** Peacebuilding and diplomatic efforts are essential in reducing food insecurity in conflict-prone regions.

Government Initiatives in India to Combat Food Insecurity

The Indian government has implemented several schemes and programs to reduce food insecurity and improve food access for its citizens. These initiatives aim to address various aspects of food security, including food distribution, nutrition, and poverty alleviation. Here are some notable government schemes and programs in India to reduce food insecurity:

1. **Public Distribution System (PDS):** The PDS is one of the oldest and most significant food security programs in India. It provides subsidized food grains such as rice, wheat, and sugar to eligible households through a network of fair price shops (ration shops) across the country. The PDS provides subsidized food grains to eligible households, ensuring basic food access across the country).

2. **Midday Meal Scheme:** This program aims to improve the nutritional status of children and promote regular school attendance. Under this scheme, free and nutritious meals are provided to students in government and government-aided schools.
3. **Integrated Child Development Services (ICDS):** ICDS is a comprehensive program that addresses the nutritional and health needs of children under six years of age and pregnant and lactating women. It provides supplementary nutrition, health check-ups, and preschool education services (Kumari, 2025).
4. **National Food Security Act (NFSA):** - NFSA, enacted in 2013, legally guarantees subsidized food grains to around two-thirds of the population, including priority households and Antyodaya Anna Yojana (AAY) households. It aims to provide food security to vulnerable sections of society (*National Food Security Act, 2013*).
5. **Pradhan Mantri Garib Kalyan Anna Yojana (PMGKAY):** - Launched as a response to the COVID-19 pandemic, PMGKAY provided additional free food grains (rice or wheat) to beneficiaries of the PDS for several months to alleviate food shortages during the crisis.
6. **Annapurna Scheme:** - This program targets senior citizens who are not covered under the NFSA. It provides 10 kg of food grains (rice or wheat) per month free of cost to destitute senior citizens.
7. **National Rural Livelihood Mission (NRLM):** - NRLM focuses on poverty reduction and livelihood promotion among rural households. It includes provisions for improving access to food and nutrition services.
8. **National Nutrition Mission (Poshan Abhiyan or PMMVY):** This initiative aims to reduce malnutrition and improve maternal and child health. It focuses on behavior change communication, supplementary nutrition, and health services.
9. **Swachh Bharat Abhiyan (Clean India Campaign):** While not directly a food security program, improving sanitation and hygiene through Swachh Bharat Abhiyan indirectly contributes to better health and reduced foodborne illnesses, thereby improving food security.
10. **Rashtriya Krishi Vikas Yojana (RKVY):** RKVY promotes agricultural development and food security by providing financial support for agricultural projects and initiatives that increase farm productivity.

These government schemes and programs collectively work to address food insecurity in India by ensuring access to food, improving nutrition, and targeting vulnerable populations. It's important to note that the effectiveness of these programs may vary across different states and regions in the country.

Conclusion

Food insecurity remains a complex and pressing global issue, with wide-reaching consequences for health, economic development, and social stability. Tackling this issue requires a multidimensional approach, combining agricultural investment, climate resilience, and social support systems. By taking decisive action, we can work toward ensuring that everyone has access to sufficient and nutritious food, paving the way for a more secure and prosperous future for all.

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WHAT'S REALLY IN YOUR FOOD? A SIMPLE GUIDE TO ADDITIVES, DYES & LABELS

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What's Really in Your Food? A Simple Guide to Additives, Dyes & Labels

Have you ever looked at a cereal box and wondered what "Yellow 5" or "BHT" meant? You are not the only one. The food we consume has many things that sound more like science experiments than a snack. Food chemicals and dyes are everywhere, from preservatives to colorants. What are they, and should you be worried?

What Are Food Additives and Dyes?

Food additives are substances added during food processing to improve shelf life, taste, texture, or appearance. They include various chemicals and natural substances like preservatives (to prevent spoilage), emulsifiers (to mix oil and water), stabilizers, sweeteners, and colorants.

Food dyes (or colour additives) are specific additives that give food a vibrant hue. These can be synthetic (like Red 40 or Blue 1) or natural (like beetroot extract or turmeric).

Common examples include:

- Sodium benzoate – a preservative found in sodas and sauces
- Citric acid – a natural flavor enhancer from citrus fruits
- Yellow 5 (Tartrazine) – a synthetic dye often found in candies
- Carrageenan – a thickener derived from seaweed

Why Are They Used?

Food manufacturers use additives and dyes for several reasons:

- Preservation: To extend shelf life and reduce food waste
- Visual appeal: Bright colours attract consumers (especially kids)
- Taste & texture: To make food more flavourful and consistent
- Nutrition: Some additives fortify food with essential nutrients (e.g., iodine in salt, iron in cereals)

Are They Safe?

Generally, yes, but it depends on the type and amount. Regulatory bodies like the FDA (USA), EFSA (Europe), and FSSAI (India) evaluate additives before approving them for use. Most approved additives are considered safe when consumed in regulated amounts.

However, some concerns remain, especially about synthetic dyes and certain preservatives. A landmark study known as the Southampton Study (2007) found that a mix of artificial dyes and preservatives may be linked to hyperactivity in children. This led to warning labels on such additives in Europe.



Other studies suggest some synthetic additives may trigger allergic reactions, digestive issues, or behavioural changes in sensitive individuals.

Decoding Food Labels

Food packaging must list all ingredients, including additives. These may appear by name or number. For example:

- E102 = Tartrazine
- E621 = Monosodium glutamate (MSG)

Pro Tip: Ingredients are listed in descending order by weight, so the earlier you see an additive listed, the more it is in the product.

Also, look out for phrases like:

- “No artificial preservatives”
- “Free from synthetic dyes”
- “100% natural” – though this claim is loosely regulated in many regions



How the World Regulates Additives

Region	Regulatory Body	Key Regulations
USA	FDA	GRAS list (Generally Recognized As Safe); premarket approval
EU	EFSA	“E numbers”: warning labels for risky dyes
Japan	MHLW	More restrictive on synthetic colorants
India	FSSAI	Specifies additive limits by food category

Each country has its own thresholds and testing protocols, but most rely on global scientific data to guide policy decisions.

Smart Consumer Tips

- Read the label — avoid foods with a long list of unfamiliar additives
- Choose whole or minimally processed foods
- Opt for organic — they often avoid synthetic dyes and preservatives
- Be cautious of brightly colored snacks, especially if they stain your tongue!

Conclusion

Food additives and dyes aren’t evil. Many play vital roles in making our food safer and longer-lasting. However, not all additives are created equal, and over time, excessive consumption may have health consequences, especially for kids and sensitive individuals.

Thanks to growing awareness, more transparent labeling, and tighter regulation, you now have the power to make better food choices. So flip that package over and get label-literate next time you’re at the store. Your body will thank you.

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ADDRESSING GLOBAL FOOD SECURITY: CHALLENGES, DRIVERS AND STRATEGIC SOLUTIONS

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Abstract

Food security represents a significant global challenge, as defined by the Food and Agriculture Organization (FAO), encompassing access to sufficient, safe, and nutritious food. Projections for 2024 indicate that over 735 million individuals may experience hunger due to escalating food prices, supply chain disruptions, climate change, and armed conflicts, particularly in Sub-Saharan Africa. Contributing factors include poverty, economic disparity, urbanization, inadequate infrastructure, and extreme weather events. Mitigating these issues necessitates investment in rural infrastructure, improved market access, and reduction of post-harvest losses. Supporting smallholder farmers through credit and technology is crucial for fostering resilience and innovation. Collaborative initiatives, such as the African Union's Agri-Boost Initiative, are essential for sustainable solutions to achieve long-term food security and economic stability.

Keywords: Climate change, Conflict and Crisis, Empowerment, Food insecurity, Strategies.

Introduction

Food security is no longer a distant issue. It's here, it's urgent, and it's global. Food and Agriculture Organization (FAO) define food security as: when people have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Food security is a vital tool for people. It holds great importance for nations who have enormous population base and weak agricultural infrastructure. Countries with very high levels of poverty and chronic malnutrition face limitations in human capital development, which is required to achieve sustainable growth. They are also at risk of mental impairment, poor health, low productivity and even death.

According to recent UN data, over 735 million people faced hunger in 2024, with rising food prices and supply chain disruptions hitting vulnerable populations hardest especially in Sub-Sahara Africa (FAO, 2006). Droughts in Africa, floods in South Asia, and geopolitical tensions in Eastern Europe have compounded an already fragile system. In some part of the world, armed conflict continues to devastate agricultural production and displace millions of people from their natural habitat. At the same time, climate change is undermining food systems through harsh weather condition and reduced crop yields (Mirzabaev *et al.*, 2023). These menaces don't just affect people's daily meals they affect nation's economies. According to literature, countries facing both high food insecurity and conflict tend to experience lower GDP growth, higher inflation, and rising political instability (FAO, 2008).

Factors Leading to Food Insecurity

Poverty and Economic Inequality

Poverty significantly contributes to food insecurity by restricting access to essential food and resources for individuals and families. It also prevents investment in sustainable agricultural practices, perpetuating a cycle of food insecurity (Cafiero, 2018). Additionally, economic inequality

intensifies these challenges, as segments of the population may struggle to afford basic meals, leading to hunger and malnutrition.

Urbanization

The global population is expected to rise from 6.7 billion in 2007 to 9.2 billion by 2050, predominantly in urban areas of less developed countries (United Nations, 2008). The Food and Agriculture Organization (FAO) forecasts that food production must increase by 60 percent by 2050 to satisfy this demand. In developed nations, urban dwellers are projected to grow from 0.9 billion in 2010 to 1.1 billion by 2050, while the rural population may decline by 0.6 billion (Corbridge, 2005; Davey, 2012). This rural decline poses significant challenges as fewer farmers will exist to meet the food demands of expanding urban populations (Ghosh *et al.*, 2024).

Climate Change and Natural Disasters

Climate change adversely affects agricultural productivity through altered rainfall patterns, rising temperatures, and increased frequency of extreme weather events, such as floods and droughts (Adedoyin *et al.*, 2011). These factors can severely damage crops, disrupt farming practices, and hinder community access to food (Leclère *et al.*, 2013). The World Bank projects that climate change could push over 100 million individuals into poverty within the next decade, directly impacting hunger rates (Lloyd *et al.*, 2011; Leichenko and Silva, 2014).

Inadequate Infrastructure and Access

Insufficient infrastructure, including roads, storage facilities, and markets, impedes the effective distribution of food from production sites to consumers. Moreover, inadequate infrastructure hampers farmers' ability to invest in sustainable practices and access market opportunities for their products (Ayinde, 2021).

Crisis and Conflict

Conflict often leads to the destruction of agricultural lands, displacing populations and instilling fear that prevents farmers from accessing their fields. Such instability contributes to inflation, rendering available food unaffordable for many (Kemmerling *et al.*, 2022). Furthermore, conflict disrupts supply chains and exacerbates global inflation rates, leaving millions without access to adequate and nutritious food.

Key strategies to mitigate Food insecurity include

1. Rural Infrastructure Investment

Investing in roads, storage facilities, energy supplies, market access, and communication networks boosts food security by improving market access through enhanced transportation that reduces post-harvest losses and lowers costs for farmers to sell produce and purchase inputs; reducing post-harvest losses with modern storage solutions like silos and cold storage that minimize spoilage and stabilize food availability; creating jobs and generating income through infrastructure development, which allows rural populations to afford better-quality food; and facilitating access to services such as extension support, weather forecasts, and market information through improved communication and energy, thereby aiding farm planning and risk management.

2. Irrigation Investment

Investing in irrigation is vital for agricultural resilience as it increases agricultural productivity by enabling multiple cropping seasons and significantly enhancing yields over rain-fed farming, provides climate resilience by buffering against erratic rainfall and droughts to ensure consistent

food availability, allows diversification of crops through reliable water sources which improves dietary diversity and nutrition, and promotes efficient water use with modern systems like drip irrigation that conserve water while increasing agricultural output and supporting sustainable practices.

3. Supporting smallholder farmers with credit and technology

When smallholder farmers are provided with both credit and technology, they can more easily adopt new innovations, maximizing the benefits of technology through financial support and enhancing the productivity, resilience, and inclusiveness of food systems; this empowerment leads to increased abundance, affordability, and diversity of food, greater self-reliance and resilience within rural communities, and a strengthened food value chain overall, making support for smallholder farmers not only a strategy to increase food production but also a powerful tool for reducing poverty.

4. Strengthening local markets and regional trade

Shorter supply chains enable food to reach markets more quickly, reducing spoilage and waste, while regional trade allows areas with food surpluses to supply regions facing shortages, supporting local farmers and encouraging diverse, resilient food production; stronger local markets create jobs and income for farmers, traders, and labourers, enhancing their ability to purchase food, and lower transportation costs from local sourcing can reduce food prices for consumers, while regional trade lessens dependence on vulnerable global imports and makes local and regional food systems more adaptable to changes in climate and economic conditions.

5. Improved Food Utilization

Local markets often support culturally appropriate and nutrient-rich foods that align with local diets, while fresh food from nearby sources can improve the nutritional value and health status of the people.

6. Empowerment and Resilience

Supporting local agriculture promotes rural development and increases women's participation in food systems, while also strengthening community resilience by building self-reliant economies that reduce dependence on foreign markets.

7. Enabling a safe environment for farmers leads to:

Creating a secure environment for farmers significantly enhances food security by fostering increased agricultural production through investment and modern technology adoption. It minimizes post-harvest losses by safeguarding crops and livestock, improves market access via enhanced infrastructure, and promotes the well-being of farmers through access to healthcare, education, and legal protections, particularly for vulnerable populations such as women and youth. Furthermore, it advocates for long-term sustainability through secure land tenure and environmentally sound farming practices, ultimately contributing to the empowerment and stability of rural communities.

Government intervention:

Several governments and international organizations are stepping up:

- **African Union** launched the 2025 "Agri-Boost Initiative" to support home-grown food production.
- **European Union** pledged €1 billion for climate-resilient agriculture.

- **World Bank** is investing in post-conflict recovery through agricultural redevelopment in regions facing conflict and unrest.

Conclusion

Food security goes beyond mere access to food; it is deeply connected to economic development, social stability, and global security. The complex, interrelated drivers of food insecurity; such as poverty, inequality, climate change, urbanization, conflict, and poor infrastructure require strategic, coordinated interventions. Investing in rural infrastructure, irrigation, smallholder farmer support, local markets, and safe agricultural environments can transform vulnerable food systems into resilient, inclusive growth engines. These measures not only enhance food availability and access but also reduce poverty, empower women, and promote sustainability. Achieving food security demands urgent, collaborative, and innovative efforts from governments, international bodies, and communities through integrated policies. Ultimately, food security is essential for global peace and prosperity and is a vital investment in a stable, nourished future.

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UNLOCKING THE POTENTIAL OF GENE EDITING IN CROP IMPROVEMENT

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Genome editing, a revolutionary technology in modern biotechnology, has transformed the landscape of crop improvement by offering precise and targeted modifications to the genetic makeup of plants. The process of targeted DNA modifications begins with the formation of nuclease-induced double-stranded breaks (DSBs), which can be repaired using one of two major processes seen in nearly all cell types and organisms: homology-directed repair (HDR) or non-homologous end-joining (NHEJ). Depending on the repair method used, this results in either targeted integration or gene disruption. The Charpentier and Doudna labs then collaborated to produce the seminal 2012 Science article that launched the CRISPR-Cas9 genome editing era. Numerous researchers have used genome editing in research and breeding efforts to create new crop types ever since the Nobel Prize-winning CRISPR-Cas9 genome editing method for plants was developed. Genome editing, as opposed to conventional breeding techniques, enables researchers to precisely alter particular genes, resulting in the creation of crops with superior qualities like increased yield, nutritional value, resistance to disease, and environmental adaptation.

Widely adopted genome editing tools:

Gene editing technology allows for precise adjustments to an organism's genome. Some of the most often used gene editing tools are:

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a bacterial defensive system repurposed for gene editing.

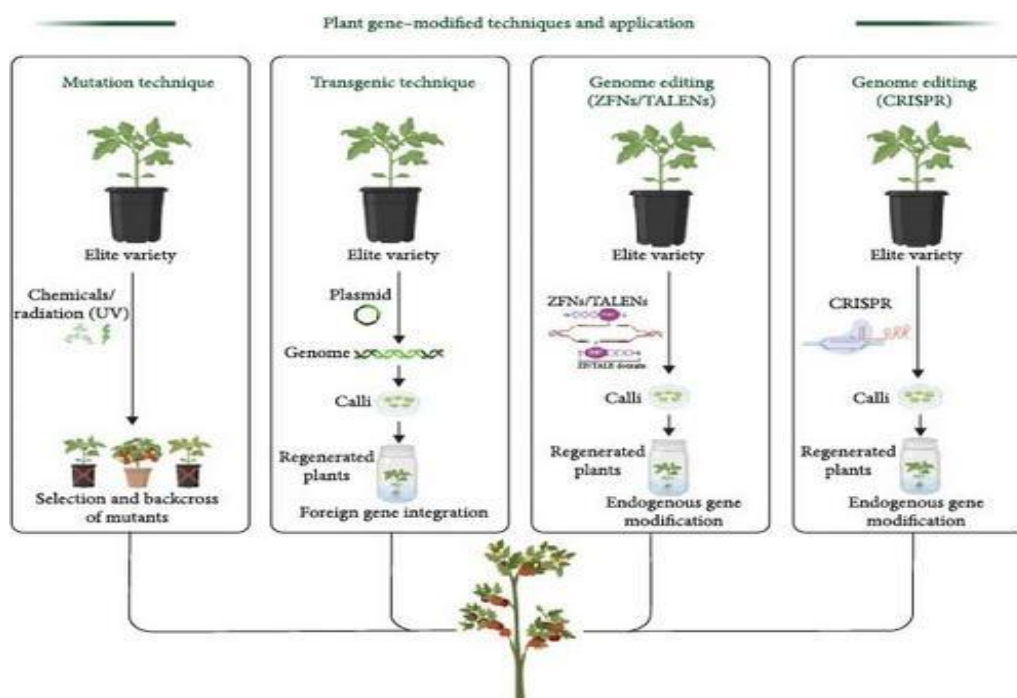
TALENs (Transcription Activator-Like Effector Nucleases): Enzymes that can be programmed to target specific DNA sequences.

ZFNs (Zinc Finger Nucleases) are another type of enzyme that can be programmed to target certain DNA sequences.

These gene editing tools have transformed genetic engineering by allowing for accurate and efficient genome alterations.

CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats-CRISPR associated protein 9), has emerged as a versatile genetic engineering tool, making it more accessible and efficient than ever before. This approach allows researchers to make targeted adjustments to crop DNA by inserting precise changes at specific spots throughout the genome. This method allows researchers to make targeted modifications to crop DNA by introducing precise changes at specified locations across the genome. As a result, genome-edited crops can be grown faster and more precisely than traditional breeding methods or previous genetic engineering techniques. Genome-edited crops have immense potential for tackling global agricultural issues. These crops, which improve crop resistance to biotic and abiotic difficulties such as pests, diseases, drought, and soil salinity, may

provide a solution to food security concerns in a changing climate. Furthermore, genome editing has the potential to increase agriculture nutritional value, reduce malnutrition, and improve worldwide human health.



The scope of crop enhancement initiatives has been considerably broadened by recent developments in genome editing technologies. New CRISPR systems, such as CRISPR-Cas12 and CRISPR-Cas13, provide more features for accurate genome editing, such as RNA editing, base editing, and epigenome editing. Researchers can now address more intricate genetic alterations and create crops with ever more specialized features to satisfy changing agricultural demands thanks to these developments. Furthermore, major advancements in a number of important crops, such as rice, wheat, maize, and soybeans, have resulted from the use of genome editing in crop enhancement. These research show how genome editing may be used to address particular issues that various crop species confront, like increased production, resistance to disease, and improved nutrition.

India's status quo on commercialisation of genome edited crops:

With major ramifications for the country's agricultural advancement, the Union Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India, announced a historic decision in April 2022. Their decision to omit certain gene-edited plants from stringent biosafety requirements suggests a possible change in strategy for agricultural advancement. In particular, the ruling exempts SDN1 and SDN2 plants from the strict prohibitions on the sale of genetically modified transgenic crops (Rules 7-11 of the Environment Protection Act). Rather, the Institutional Biosafety Committee will serve as the basis for authorities to verify that the gene-edited crop is free of foreign DNA. This ruling enables the field testing of crops created using the SDN-1 and SDN-2 methods, which produce plants free of exogenously added DNA. Potential commercial release is made possible by these experiments. Through SDN-1 and SDN-2, particular features inside a gene can be altered or improved without adding additional genetic material. Nonetheless, SDN-3-derived products, which do add foreign genes, remain classified as genetically modified organisms. The only

genetically modified crop that is currently permitted for cultivation is insect-resistant Bt cotton, which was approved in 2002.

Products/Research under consideration

- **Pest and disease resistant mustard, 2023:** Scientists from Delhi University's Centre for Genetic Manipulation of Crop Plants (CGMCP) and the Indian Council of Agricultural Research employed CRISPR-Cas9 to create a less fragrant mustard with considerably greater glucosinolate levels. Multiple homologues of the glucosinolate transporter GTR1 and GTR2 genes were targeted to produce a low-seed, high-leaf glucosinolate oilseed mustard with unrivaled defense and yield potential. Field testing is scheduled to begin in 2024.
- **Drought resistant rice, 2022:** It is expected to be commercially accessible in 2026. The Indian Agricultural Research Institute targeted the drought and salt tolerant (OsDST) gene, which resulted in the development of drought-resistant rice.
- **Vitamin A-fortified banana, 2020:** Researchers at the National Agri-Food Biotechnology Institute employed CRISPR to biofortify bananas, thereby addressing vitamin A shortage in developing countries. The lycopene epsilon-cyclase gene was altered, leading to a 6-fold increase in β -carotene production and decreased α -carotene and lutein levels.

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GENOME-EDITED RICE: A LEAP FORWARD OR A REGULATORY RISK?

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Abstract

On May 4, 2025, India unveiled its first genome-edited rice varieties, DRR Dhan 100 and Pusa DST Rice 1, marking a major milestone in agricultural biotechnology. Developed by the Indian Council of Agricultural Research (ICAR), these varieties are expected to lead the second green revolution by increasing yields by 30%, improving drought resistance, and reducing water usage. However, the lack of a comprehensive regulatory framework for genome-edited crops has sparked controversy. Although ICAR claims that existing regulations are sufficient, critics argue that the lack of specific guidelines and mandatory labeling threatens transparency, biosafety, and consumer confidence. This article explores the potential of genome-edited rice to transform Indian agriculture, the regulatory challenges it faces, and the need for balanced regulation to ensure safety and sustainability.

Keywords: DRR Dhan 100, Drought resistance, Genome-edited rice, Pusa DST Rice 1

Introduction

India, known as the world's second-largest rice producer, has been facing the tough task of feeding its ever-growing population while dealing with limited farmland and water resources. On May 4, 2025, the launch of genome-edited rice varieties, DRR Dhan 100 and Pusa DST Rice 1, marks a significant move towards tackling these issues. Developed with the innovative CRISPR-Cas technology, these new rice types are expected to enhance yields by 20–30%, lessen irrigation demands by a staggering 7,500 million cubic meters, and lower greenhouse gas emissions by 20% over an area of five million hectares. Union Agriculture Minister Shivraj Singh Chouhan described this development as a "historic milestone," hinting at the dawn of a second Green Revolution.

However, the enthusiasm surrounding these advances is somewhat moderated by worries about the absence of a specific regulatory framework for genome-edited crops. This gap raises important questions regarding safety, transparency, and the potential long-term effects on the environment. This article delves into the ground-breaking potential of genome-edited rice, explores the regulatory situation in India, and considers the global perspective on gene-editing regulations. By including expert opinions, recent updates, and critical viewpoints, it aims to evaluate if India's approach finds the right balance between embracing innovation and exercising caution.

The Promise of Genome-Edited Rice

The Indian Council of Agricultural Research (ICAR) has created two new rice varieties, DRR Dhan 100 and Pusa DST Rice 1, using a cutting-edge tool called CRISPR-Cas. This technique allows for precise editing of the plant's own genes without adding any foreign DNA. Unlike traditional genetically

modified (GM) crops that typically incorporate genes from other organisms, these new varieties utilize methods known as Site-Directed Nuclease 1 (SDN-1) and Site-Directed Nuclease 2 (SDN-2). These methods result in mutations that are similar to those that happen naturally in nature.

ICAR believes that these new crops have the potential to boost rice production by an impressive 4.5 million tonnes each year. They also promise to cut down on water usage and reduce the growing time by about 20 days, which could help save precious water resources and lower emissions. In the 2023–24 season, India produced 137 million tonnes of rice, and this figure is expected to climb to 147 million tonnes in 2024–25. These new varieties could add even more to that total. Given that rice covers 40% of India's farmland and feeds millions of people, such advancements could play a significant role in enhancing food security and sustainability.

Experts like Ajay Kakra from Forvis Mazars suggest that these innovations could position India as a leader in biotechnology, as long as the processes for field trials and regulations remain clear and open. Recent news has shown that ICAR is broadening its gene-editing research to include 24 food crops and 15 horticultural crops, indicating a serious commitment to agricultural progress.

Corteva Agriscience, a prominent global seed company, backs this approach, highlighting that gene editing could make crops more resilient against pests and the stresses of climate change. This presents a valuable opportunity for addressing global food security challenges.

Regulatory Framework: Adequate or Absent?

The regulatory stance of India regarding genome-edited crops has ignited a fiery debate. The Indian Council of Agricultural Research (ICAR) argues that the current rules under the Manufacture, Use, Import, Export, and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells, Rules, 1989, are adequate. Edits categorized as SDN-1 and SDN-2, which don't involve the introduction of foreign DNA, are exempt from certain regulations outlined in the Environment (Protection) Act of 1986, since they mirror natural or induced mutations.

A memorandum released by the Ministry of Environment, Forest, and Climate Change in 2022 provided more clarity on this exemption, supported by the Department of Biotechnology's draft guidelines and Standard Operating Procedures from 2020. Devendra Kumar Yadava, who serves as the Deputy Director General at ICAR, stands firm in defending this regulatory framework. He maintains that genome-edited plants are initially subjected to GMO regulations, and exemptions are granted only after it's confirmed that there's no foreign DNA present.

On the flip side, critics like Devinder Sharma, an expert in agriculture, voice strong concerns. He believes this wave of deregulation is a sign of corporate influence, allowing companies to sidestep critical safety testing. Sharma points to the European Union's tough regulations on GMOs, which demand thorough testing and labeling for gene-edited crops, suggesting that India should follow suit.

The Coalition for a GM-Free India shares these worries, denouncing the deregulation of SDN-1 and SDN-2 edits as "illegal" and "unscientific." They argue that, while gene editing may be precise, it is still a form of genetic modification that could lead to unintended effects, thereby requiring comprehensive biosafety evaluations. Ashok Kumar from Transform Rural India stresses the importance of rigorous testing for staple foods like rice, to ensure they are safe for both human and animal consumption.

Regulatory approaches around the world show significant variation. The EU's stringent oversight is in stark contrast to the more lenient systems in the US and Japan, where SDN-1 and SDN-2 edits often slip through without regulation. Recent discussions on X reveal a growing public scepticism, with users raising questions about the absence of labeling and the lack of long-term ecological data. A study published in *Nature Biotechnology* in 2025 further emphasizes the necessity for standardized global regulations. It points out that off-target mutations in CRISPR-edited crops might present unexpected risks, highlighting the need for caution in this rapidly evolving field.

Challenges and Concerns

The lack of mandatory labeling has become a heated issue. Without clear signs to differentiate gene-edited rice from traditional varieties, consumers may lose trust in what they're buying. Deepak Pareek, an agricultural economist, points out the urgent need for simpler regulations and efficient seed distribution systems to ensure that the commercial rollout can happen within the next four to five years. He raises important ecological concerns too, noting the potential impacts on soil health and biodiversity over five million hectares. Additionally, there are worries about the intellectual property issues linked to CRISPR tools.

India's rich variety of rice genetics, which includes thousands of native types, is another big worry. Critics argue that if genome-edited rice becomes widespread, it could push traditional varieties to the sidelines, jeopardizing cultural heritage and hurting the market for non-GM rice exports. A report from the International Rice Research Institute in 2024 highlighted that India's non-GM rice varieties are highly valued in markets such as Europe, where scepticism towards GMOs is prevalent.

Public acceptance of this technology is still a significant challenge. The Coalition for a GM-Free India claims that the biotech industry tends to downplay the risks associated with gene editing in order to combat the resistance faced by transgenic technologies. On social media, particularly on X, discussions show a mix of opinions. Some users celebrate the potential for higher yields, while others call for more transparency and independent safety studies.

The Path Forward

For India to unlock the potential of genome-edited rice, it's crucial to strike a balance between fostering innovation and exercising caution. Conducting thorough and transparent field trials across various agroclimatic regions is vital to confirm the claims about the rice's performance. A strong regulatory framework that includes mandatory labeling and long-term ecological studies can help address consumer concerns and environmental issues. Additionally, educating farmers and engaging stakeholders will be key to gaining trust and ensuring widespread adoption.

Recent developments indicate some progress. In October 2025, the Department of Biotechnology revealed plans to update its 2020 guidelines, taking into account public input and global best practices. This revision could enhance oversight while encouraging innovation. Experts like Pareek and Kakra suggest a gradual approach, starting with pilot projects to assess both ecological and economic effects before moving to full-scale commercialization.

Looking at the bigger picture, genome-edited rice has the potential to transform Indian agriculture by decreasing water usage and emissions while improving crop yields. However, without strong regulations in place, the excitement surrounding a new Green Revolution could be clouded by distrust and unintended consequences. Ultimately, India's role as a leader in biotechnology depends on its capacity to tackle these challenges in a transparent and inclusive manner.

Conclusion

The arrival of genome-edited rice varieties is a significant turning point for agriculture in India. These advancements promise to tackle urgent issues such as water shortages and food security. However, the absence of a solid regulatory framework raises important questions about safety, transparency, and the impact on the environment. By looking at successful global examples, prioritizing thorough testing, and involving all stakeholders in the conversation, India has the opportunity to leverage gene editing effectively. This approach can help protect its agricultural heritage and maintain consumer trust. The conversation surrounding genome-edited rice is more than just a scientific discussion. It's about finding the right balance between innovation and responsibility in a world that is increasingly seeking sustainable solutions.

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GI TAGS: A PATHWAY TO PROVIDE OWNERSHIP FOR THE FARMERS

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Introduction

Agricultural products are often deeply linked to the geographical origin, climatic conditions, traditional knowledge, and farming practices of specific communities. In India, a large number of such unique products have been practiced and preserved over centuries. However, until recently, farmers had little or no legal ownership over these products, exposing them to imitation and exploitation. Geographical Indications (GI) provide a statutory framework to protect such products and give rightful recognition and economic benefits to the original producers. Geographical Indications (GI) have emerged as an important form of intellectual property that not only protects the uniqueness of regional products but also acts as a tool for rural development and farmer empowerment. This article explores how GI tags provide farmers with legal ownership over traditional agricultural produce, enhance market recognition, prevent misappropriation, and ultimately lead to increased economic and cultural sustainability.

Understanding Geographical Indications (GI)

As per the World Intellectual Property Organization (WIPO), a Geographical Indication is a sign used on goods that have a specific geographical origin and possess qualities, reputation, or characteristics essentially attributable to that location.

In India, GI registration is governed by the Geographical Indications of Goods (Registration and Protection) Act, 1999, which came into effect in 2003. The registration provides legal protection to unique products associated with specific regions, preventing unauthorized use and imitation.

Objective

To provide registration and better protection for geographical indications related to goods. This helps in preserving the unique qualities associated with products originating from specific regions (IPI, 2024).

Agricultural Relevance of GI Tags

Out of the total registered GI products in India, a significant share belongs to the agricultural sector. Agricultural crops constituted only 31.10 per cent of the total registered GIs (Reddy and Prasanna, 2024) even though the first registered product is from agriculture sector. Darjeeling Tea holds the prestigious status of being the first product in India to receive a Geographical Indication (GI) tag in 2004 (Das, 2006). However, the current number of GI registrations, particularly in the agriculture and food sectors, remains significantly below its true potential (Nirosha and Mansingh, 2024).

From the viewpoint of the global value chain approach applied to agro-food supply chains, Geographical Indications (GIs) can support the upgrading of small-scale producers in three key ways: by helping them capture greater value or profit margins, encouraging collective action and organization among producers, and enabling diversification into value-added activities such as downstream processing (Tregear, 2016). Geographical Indications (GIs) not only yield greater

economic returns compared to normal products but also boost the agricultural economy by advancing the trade of agricultural products and increasing their market value (Li *et al.*, 2023). Several meta-analysis-based studies have found a strong positive correlation between Geographical Indication (GI) products and increased farm incomes, as well as between GIs and higher prices for agricultural products (Li *et al.*, 2024). However, a critical review of economic literature on GI tagging from the last decade revealed that price premiums associated with Geographical Indications (GIs) are typically attainable only in the long run, and only a select group of specialty GI products are likely to secure such premiums (Torok *et al.*, 2020).

The Indian government has launched various initiatives to promote Geographical Indication (GI) products in global markets. The Agricultural and Processed Food Products Export Development Authority (APEDA) has conducted virtual buyer-seller meetings and promotional events in countries like Belgium and Denmark. Additionally, APEDA has supported the export of several GI-tagged products such as Naga Mircha, Black Rice, Assam Lemon, and various mango varieties to international destinations (Nirosha and Mansingh, 2024).

Iconic examples of agricultural products include:

Darjeeling Tea - the first Indian product to be registered as a GI in 2004 for the word and logo. Basmati Rice- recognized for its aroma and long grain. Guntur Sannam Chilli is renowned for its intense pungency and unique long, slender shape. It is also distinguished by its bright red colour and thick skin. Alphonso Mango, Kashmir Saffron, Naga Mircha, Sikkim Large Cardamom, and Coorg Orange - all represent distinct agronomic and cultural identities.

These tags validate the regional origin, thereby promoting authenticity and consumer trust.



Figure 1: GI tagged products of some famous agricultural products
(Source: Google)

GI Tags as a Tool of Ownership and Empowerment

Legal recognition and protection

GI registration empowers producer groups, farmers, and cooperatives with collective ownership rights over the product. This means only the registered users or authorized producers from the specific region can market the product under that name, offering protection against exploitation by external commercial entities.

Prevention of biopiracy and misappropriation

Many traditional agricultural products are at risk of biopiracy or misbranding. GI registration acts as a deterrent against such misappropriation. For instance, the GI status of Basmati Rice has played a crucial role in India's legal battles to protect its brand globally.

Preservation of indigenous knowledge

GI protection ensures the preservation of traditional farming methods, seed varieties, and cultivation techniques, thus maintaining agrobiodiversity and sustainable practices.

Boosts the economy by value addition and branding

GI status adds branding power to local produce. GI-tagged products can fetch higher prices compared to their non-GI counterparts, thereby improving farmers' income. GI tags motivate local producers by ensuring they receive fair market value for their products. They strengthen local economies by supporting farmers and artisans, promoting fair trade practices, and enabling better pricing.

Policy and institutional framework

The Geographical Indications Registry, located in Chennai, facilitates the registration process. The Agricultural and Processed Food Products Export Development Authority (APEDA) and the Ministry of Commerce & Industry support the international promotion of GI products. And some boards like Spice Board, Tea Board, and Coffee Board, etc., also help in the Institutional support for the GI tags registrations.

Challenges in Implementation

Lack of awareness among farming communities about the benefits and the process of GI registration. Time-consuming for registration, legal assistance, and compliance. And delays in acceptance. Inefficient post-GI marketing and value chain support leads to underutilization of the potential economic benefits. Limited export recognition- only a few Indian GIs are recognized globally under mutual agreements (e.g., Darjeeling Tea in European nations).

Recommendations

Establish regional GI facilitation centres to provide technical and legal assistance to farmers. Encourage FPOs and cooperatives to participate in GI registration and collective marketing. Strengthen supply chain and export promotion mechanisms for GI products. Incorporate GI education in rural extension programs and agricultural curricula.

Conclusion

Geographical Indications serve not just as labels of uniqueness, but as instruments of legal ownership, economic empowerment, and cultural preservation for Indian farmers. With adequate institutional support and awareness, GI tags can pave the way for a more inclusive, equitable, and sustainable agricultural economy, where the rightful custodians of traditional produce, the farmers are recognized and rewarded.

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CAREER DIRECTION AFTER B.SC. AGRICULTURE: GUIDANCE FOR STUDENTS

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Introduction:

- Few lines on relevance and importance of B.Sc Agriculture.
- The growing prospects of the agriculture sector at present.
- It is natural for this question to arise in the minds of students that B.Sc. After agriculture, in which private or government sector should I make my future?

Example:

In today's time, agriculture is not limited to only farming, but it has also become a rich field of technology, business and research. After doing BSc Agriculture, students have many possibilities. And what are those possibilities? In this article, we will discuss these options in detail.

After B.Sc. Agriculture, there are numerous avenues open to you - whether it is higher education, government service, job in a private company or starting your own business. The most important thing is that you choose the right option according to your interest, qualification and dreams.

Higher education options-

If you want to understand agricultural science or want to deeper your knowledge, then M.Sc. is a great option. You can choose any specific subject according to your interest, such as:

MSc Agriculture—Different disciplines

- 1- Agronomy
- 2- Soil science
- 3- Horticulture
- 4- Plant Pathology
- 5- Entomology
- 6- Agricultural extension
- 7- Agricultural Economics
- 8- Genetics and Plant Breeding

MBA: MBA is a good option for those interested in agricultural business management. With this, you can make a career in marketing of agricultural products, supply chain, agri-input private and limited companies and export sector.

PhD: If your aim is to do research or become a professor in a university, then doing PhD is a must for you golden carrier.

In India

- Indian Agricultural Research Institute New Delhi.
- Dr. Rajendra Prasad Central Agricultural University Pusa, Samastipur Bihar. Central Agricultural University Manipur Imphal.

- Chaudhary Charan Singh Agricultural University Haryana.

UP CATET (Uttar Pradesh Combined Agriculture and Technology Entrance Test) in Uttar Pradesh has five agricultural universities under it which are as follows-

- Chandrashekhar Azad University of Agriculture and Technology, Kanpur.
- Narendra Dev University of Agriculture and Technology Ayodhya.
- Sardar Vallabhbhai Patel University of Agriculture and Technology Modipuram Meerut.
- Banda University of Agriculture and Technology Banda.
- Mahatma Buddha University of Agriculture and Technology, Kushinagar.

Education abroad (Other Country): Scholarships and programs offered

Government Job Opportunities

- Agriculture Officer-State governments regularly recruit for the posts of Agriculture Officer and Assistant Agriculture Officer.
- IBPS AFO (Agricultural Field Officer)

Opportunity to work as an agricultural expert in the banking sector. Both salary and workplace are good in this.

Other government institutions

- Indian Council of Agricultural Research
- FCI (Food Corporation of India)
- NABARD (National Bank for Agriculture and Rural Development)
- Agriculture Department and State PSC Exams
- Jobs in State Agriculture Department
- Career as a Scientist in Agricultural Research Institutes

Opportunities in the private sector

- Jobs in agri-business companies
- Fertilizer, pesticide and seed companies
- Farm Manager, Field Officer, Technical Sales Officer
- Employment in Agri-Tech Startups
- Seed and pesticide producing companies
- Farm Manager & Agri Project Manager
- technical sales officer
- Agri-tech companies (Ninjacart, DeHaat, Agrowave Godrej Agrovet Limited.
- Syngenta, UPL Limited,
- Nuziveedu Seeds Limited
- Advanta Limited
- Agroplast Industries
- Agro Bio Chemical
- Grow More Agri Solutions pvt Ltd.

Entrepreneurship and Startups : If you want to do something new instead of doing a job, then this area is for you.

Organic Farming : The demand for organic products is increasing rapidly. You can buy organic vegetables. You can grow fruits or grains and sell them online.

Dairy Farming : Good profits with low investment and subsidy available from the government.

Poultry / Fisheries

Agri-tech startups

Drone Survey, Technology startups like soil testing, crop health analysis have a bright future.

- Mushroom Farming
- Beekeeping
- Agriculture related services (like drone surveys, soil testing)
- Lac rearing (Sericulture)

Skill development and courses

If you want to master a particular field in a short span of time, then these courses may be beneficial:

- Digital Farming, GIS, Drone Operation
- Farm Machinery Training
- Marketing and Supply Chain Management Courses
- Drone Technology
- Supply Chain Management
- Farm Machinery Operations
- GIS and Remote Sensing
- Digital Agriculture and Data Analysis

Conclusion

- While choosing a career, keep in mind your interests and skills.
- The future of agriculture is bright — you just need to take steps in the right direction.
- Calculate on your mind SWOT (Strength, Weakness Opportunity Threats) Analysis.

EXPLORING ECO-TOURISM'S ROLE IN SUSTAINABLE DEVELOPMENT

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Abstract

Eco-tourism serves as a crucial pillar in sustainable development by harmonizing economic growth, environmental conservation, and social well-being. This paper explores how eco-tourism supports local economies through job creation and investment, while simultaneously preserving biodiversity and cultural heritage. By promoting responsible travel practices and community engagement, eco-tourism fosters long-term ecological balance and socio-economic stability. However, challenges such as over-commercialization and regulatory gaps must be addressed to ensure its effectiveness. Through strategic management, policy development, and education, eco-tourism can continue to be a powerful force for sustainability.

Key word: Eco-tourism, Economic Benefits, Social and Cultural Benefits.

Introduction

Ecotourism offers a sustainable model with the potential to transform the tourism industry, through environmental and social-economic benefits to the communities and meaningful experiences to the travellers. Ecotourism is a new concept in tourism, which was originally sparked off by the idea of making harmonious co-existence with nature a reality once again. Ecotourism interest a lot of tourism planners and marketers. There are various assumptions associated with the potential of this sector. Ecotourism is the fastest growing sector of global tourism industry (Roberts and Thanos, 2003).

Ecotourism is eco-friendly tourism responsible for travel to green areas without impacting the local community. Further, this can be helpful in the conservation of our ecosystem. Everyone adores visiting different natural areas where they can get mental peace and relaxation. Thus, every year lots of traveller's ride to tourist attractions. Through this, the tour and travel industry have become the world's largest growing industry. However, the growing tourism industry needs to learn environment-friendly or sustainable tourism that is ecotourism.

Ecotourism falls under the umbrella of sustainable tourism. The acknowledged potential of ecotourism as a workable tool for sustainable development is the main reason developing countries are increasingly welcoming it and integrating it into their plans for economic growth and environmental protection. Ecotourism is a different type of travel when visitors visit natural areas for educational purposes, research purposes, or to participate in eco-friendly activities. It's an outdoor activity that promotes the social and economic development of the surrounding areas. The primary focus is on engaging with and gaining knowledge about nature, encompassing the indigenous plants, animals, and their environments, in addition to the topography and cultural relics. When this concept is put into practice by careful planning, reasonable legislation, and sensitive execution, the environment and tourist activities may live in a complex and symbiotic connection. Well-planned ecotourism destinations can provide immediate benefits that can help offset the negative impacts of other, less sustainable uses of natural and cultural resources. These include village-based destinations with residents. Natural resources, ecotourism, rural lifestyles, cultural heritage, and integrated tourism are a few of the local economy's endeavors.

Ecotourism helps in community development by providing the alternate source of livelihood to local community which is more sustainable. Its goals are to preserve biological variety in particular and to ensure the sustainable use of resources, which will benefit the environment, provide tourists with an ecological experience, and generate revenue. However, achieving the aims in ecotourism depends on whether they are environmentally and ecologically sustainable and economically applicable. Ecotourism helps in involving local community for the conservation of the ecology and biodiversity of the area that biodiversity in return provides the economic incentives to the local community. It contributes to conservation of biodiversity; sustains the well-being of local people; involves responsible action on the part of tourist and the tourism industry; promotes small and medium tourism enterprises; requires lowest possible consumption of natural resources; stresses local participation, ownership, and business opportunities, particularly for rural people; and above all includes the learning experiences.

Definition of Ecotourism

According to The International Ecotourism Society (TIES), ecotourism can be defined as “responsible travel to natural areas that conserve the environment, sustains the well-being of the local people, and involves interpretation and education”. Such traveling can be created thanks to an international network of individuals, institutions, and the tourism industry where tourists and tourism professionals are educated on ecological issues.

Ecotourism: Definition and Concept

It is a type of tourism between seeing clean and relatively undisturbed natural areas thought to be a low-impact and often small alternative to standard commercial mass tourism. Its motivation resides in training the explorer to provide assets to natural preservation for legitimately profit from the money-related turn of events and political strengthening of nearby networks or to encourage regard for various societies and human rights.

Ecotourism can be a tool that can make tourism a good servant-fire for positive things. Cooking food for locals and impacting the environment. The emergence of ecotourism began in the early '80s. Tourism's conscious link to environment is often attributed to this. It evolved from early nature tourism to the need to include communities – it evolved from early nature tourism to include

communities. Local host communities and their culture are considered when considering local host communities.



Types of Ecotourism

1. Maas Tourism:

- The primary motivation for earning augmentation is driven by short-term, free-market principles in a classic tourism system.
- Mass tourism can be measured in terms of employment and infrastructural earnings from transportation, as well as foreign exchange earnings.
- **Alternative Tourism:**
- Alternative tourism is the complementary approach to tourism and becomes a better option than mass tourism.
- According to Fennell: "Alternative tourism is a generic term that encompasses a whole range of tourism strategies (e.g., appropriate, eco, soft, responsible, people to people and green tourism) all of which purport to offer a more benign alternative to conventional mass tourism in certain types of destination."

Educational: When you tend to visit a place to learn about the different aspects of acquiring knowledge and collecting evidence for any research project, that type of tourism is known as educational tourism.

Scientific : Scientific tourism refers to travel to a location in order to acquire scientific information. In order to learn more about the research facilities and breadth of studying and working in a particular university or sector, students often visit universities, museums, laboratories, etc.

Adventure: Adventure tourism is a type of travel where visitors explore and engage in various risk-taking activities or experiences. As an illustration, consider skydiving, scuba diving, rock climbing, hiking, trekking, bungee leaping, and bamboo rafting. These kinds of adventures are planned by people to get over their phobias and boost their endorphin and adrenaline levels.

Agri-tourism: Activities carried out on private agricultural properties are referred to as "farm recreation." These activities may include overnight stays, educational pursuits, etc. This type of tourism is a component of the agritourism sector, which is a broader industry. "A commercial enterprise conducted for the enjoyment of visitors at a working farm, or agricultural plant that generates supplemental income for the owner" is what agritourism refers to. Agri-tourism

is another great way to explore and experience nature. We visit agricultural fields, vineyards or grape yards, farms, etc., to learn more about the overall process of food production.

Rural Tourism : Rural tourism is an activity that directly and indirectly contributes to the development of rural areas. But this development must be sustainable. To this end, appropriate policies must be prepared and implemented, which will have a positive impact on these areas from the economic, social and environmental aspects, in accordance with the goals of sustainable development. This study analyzed the role of rural tourism in promoting sustainable rural development that creates jobs and promotes local culture and products.

Major Eco-Tourism Destinations in India:

- Kerala
- Sundarban Eco-Tour
- Goa Eco-Tour Himalayas
- Andaman and Nicobar Islands
- Coorg
- Deserts of Rajasthan
- Uttaranchal
- Corbett National Park
- Bharatpur Bird Sanctuary
- Gir National Park
- Sikkim
- Kodaikanal

Impact of Ecotourism

Environmental Impact:

- Reduce pollution and waste by promoting responsible use of natural resource
- Environmental protection and conservation
- Enhanced resource management techniques
- Conservation of biological diversity.
- Tourism help to ensure higher water quality and better protection of nature and local natural resource.

Socioeconomic and cultural impacts of Ecotourism:

Impact	Source
Expanding citizens' options for employment	➤ Direct employment is produced by ecotourism for managers, researchers, guides, etc. ➤ Tourism indirectly generates jobs due to visitor demands for lodging, food, travel, and mementos.
Additional regional income	➤ Direct profits from ecotourism businesses and park admission fees -indirect profits from nearby restaurants, lodging facilities, bars, and arts and crafts businesses as well as the taxes these businesses generate ➤ The addition of "hard currency"

Impact	Source
Enhanced coziness and living circumstances	➤ Locals can use amenities including roads, trails, lookouts, shelters, and restrooms that were primarily constructed for tourists ➤ Improved transportation connections in and out of areas where Ecotourism occurs
Elements of traditional culture are revalued	➤ Strong interest of Ecotourists in local cultures
Improved Education for (young) locals	➤ Local guides are essential to ecotourism and must be qualified ➤ Conversations with visitors enhance language and general education abilities ➤ Operators of ecotourism provide basic education to local youngsters and/or environmental education to the community. ➤ Locals spend considerable amounts of the money, they earned through Ecotourism, for their children's education

The benefit of Ecotourism for local people

- Travelers want to explore nature while minimizing their impact on the environment.
- One of the main benefits of ecotourism is that it reduces pollution and waste by promoting responsible use of natural resources.
- Ecotourism can bring many benefits to both travelers and local communities.
- It can help support local economies by creating jobs and income opportunities for people living near touristic destinations.
- Ecotourists have the opportunity to learn more about a culture's customs, beliefs, language, and food habits.

Conclusion

Eco-tourism serves as a vital medium for promoting sustainable development by harmonizing environmental conservation, socio-artistic integrity, and profitable viability. Empirical substantiation suggests that when managed responsibly, eco-tourism can alleviate anthropogenic pressures on natural ecosystems, foster biodiversity conservation, and enhance original livelihoods through community-grounded resource operation. Likewise, eco-tourism stimulates environmental education and cross-cultural understanding, thereby buttressing global sustainability pretensions outlined in the United Nations 2030 Agenda. Still, the effectiveness of eco-tourism as a sustainable development strategy is contingent upon rigorous policy perpetration, nonstop ecological monitoring, and stakeholder collaboration. Unborn exploration should prioritize integrative approaches that incorporate ecosystem services valuation, participatory governance models, and adaptive operation fabrics to optimize the long-term socio-ecological benefits of eco-tourism.

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FROM FRAGMENTATION TO INTEGRATION: TRANSFORMING INDIAN FARMS WITH THE INTEGRATED FARMING SYSTEM APPROACH

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Introduction

Agriculture in India is increasingly challenged by declining soil fertility, rising input costs, climate variability, and fragmented landholdings. In this context, the Integrated Farming System (IFS) emerges not merely as an option but as a comprehensive farming strategy for ensuring economic viability, ecological sustainability, and nutritional security (Kumar *et al.*, 2018).

IFS is not a new concept, and it has roots in traditional Indian agriculture, where farmers naturally practiced multi-enterprise systems. However, what distinguishes modern IFS is the scientific integration of farm components using systems thinking, enterprise modelling, and agroecological principles.

Defining Integrated Farming System

The Integrated Farming System (IFS) refers to a coordinated and synergistic integration of various agricultural enterprises such as cropping, livestock, fisheries, poultry, horticulture, agroforestry, mushroom, beekeeping, biogas, etc., within the farm, wherein wastes/by-products of one enterprise serve as inputs to another. It is a low external input and sustainable agriculture (LEISA) model that enhances input use efficiency, reduces environmental risks, and promotes economic resilience.

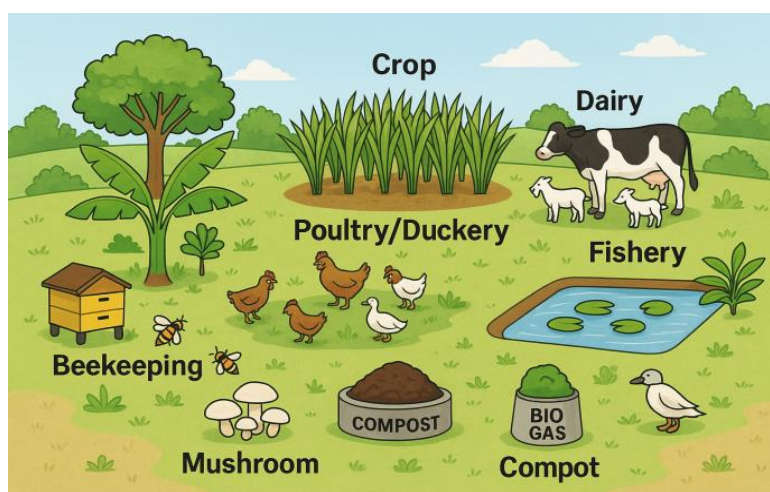


Figure 1. Integrated Farming System

Rationale for IFS in Indian Agriculture

India has 85% small and marginal farmers, holding less than 2 hectares of land. These farmers struggle to generate sufficient income from monocropping or single-enterprise farming. IFS offers them:

- Diversified and stable income sources (Rangaswami *et al.*, 1999; Ganesan *et al.*, 1999)
- Employment throughout the year (Kumar *et al.*, 2015)

- Sustainable use of natural resources (Gill *et al.*, 2009)
- Increased resilience to climate change
- Improved household nutrition and food security

Core Principles of IFS (Kumar *et al.*, 2018)

1. **Biological Integration:** Linking enterprises to maximize synergies and nutrient flows.
2. **Resource Recycling:** Using organic residues and wastes within the system.
3. **Complementarity:** Choosing enterprises that complement each other in resource use.
4. **Optimization, not maximization:** Focusing on overall farm productivity, not yield of individual crops.
5. **Adaptation to local agro-ecological conditions.**

Table 1: Components of IFS and Their Interlinkages

Enterprise	Contribution and Role
Cropping System	Base component. Provides food, fodder, and crop residues used in compost or as mulch.
Dairy	Generates milk, dung for compost/biogas, and draft power in some areas
Poultry/Duckery	Provides quick returns. Manure is rich in nutrients for compost/fish ponds.
Fisheries	Efficient use of water bodies. Fish feed on organic residues
Agroforestry	Enhances soil fertility, offers fodder, fuelwood, and carbon sequestration.
Mushroom	Converts crop residues into protein-rich food.
Beekeeping	Promotes pollination and provides honey and wax
Biogas Unit	Converts animal dung into cooking gas and slurry for soil fertility.

Example of synergy: Rice straw → Mushroom bed → Residue for cattle → Dung for biogas → Slurry for vermicompost → Used in rice fields → Repeat cycle.

A Few Examples of Integrated Farming System Models

1. Paddy + Fish + Duck + Vegetable
2. Pearl millet + Goat + Agroforestry + Horticulture
3. Rice + Dairy + Poultry + Biogas + Banana
4. Maize + Vegetables + Beekeeping + Agroforestry
5. Pulses + Goats + Azolla + Vermicompost

Economic and Ecological Benefits

Economic Efficiency

- A well-designed IFS model can increase farm income by 2–3 times over conventional cropping.
- Livestock and poultry ensure daily cash flow, while crops and horticulture provide seasonal income.
- Risk minimization—loss in one component (e.g., crop failure) can be compensated by another.

Nutrient Cycling and Soil Health

- Crop residues and animal dung enrich soil organic carbon and improve microbial activity.
- Reduces dependence on chemical fertilizers, thus lowering cost and improving sustainability.

Water Use Efficiency

- Use of farm ponds supports irrigation, fishery, and livestock watering.
- Intercropping, mulching, and agroforestry reduce water loss through evapotranspiration.

Climate Resilience

- System diversification buffers climatic shocks.
- Perennial components like trees stabilize the microclimate and reduce erosion

Constraints in IFS Adoption

- Lack of technical knowledge among farmers.
- Initial capital requirement for infrastructure.
- Labour intensiveness may not be suitable for ageing households.
- Fragmented land holdings limit component integration.
- Market linkage challenges for perishable and diversified products.

Way Forward and Recommendations

1. **Capacity Building** through on-farm demonstrations, training, and ICT tools.
2. Promote **cluster-based IFS models** for collective benefits and marketing.
3. **Policy convergence** of agriculture, rural development, livestock, and water sectors.
4. **Incentivize IFS adoption** under sustainable agriculture and carbon credit programs.
5. Strengthen **research-extension-farmer linkage** for technology backstopping.

Conclusion

Integrated Farming System is a scientific, sustainable, and socially inclusive farming strategy, particularly suited for Indian conditions. It provides a multi-dimensional solution to modern agricultural challenges by integrating productivity, profitability, resource conservation, climate resilience, and nutritional security. With the right institutional support and farmer capacity, IFS has the potential to transform Indian agriculture from a subsistence-driven to a resilient and remunerative enterprise.

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IMPROVING AGRICULTURAL FINANCE IN INDIA : INSTITUTIONS AND ACCESS

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Abstract

Agricultural finance is a critical enabler for India's agrarian economy, which supports over half of the population and contributes around 17–18% to the Gross Domestic Product (GDP). Despite several institutional frameworks and policy initiatives, timely and adequate access to agricultural finance remains elusive, especially for small and marginal farmers. This article explores the institutional ecosystem of agricultural finance in India, assesses gaps in financial inclusion, and evaluates reforms and innovations aimed at improving credit access and delivery. The analysis includes public institutions, cooperative structures, commercial banks, microfinance entities, fintech solutions, and government schemes.

Introduction

India's agricultural sector is characterized by small landholdings, dependence on monsoons, and low productivity. Financing agricultural activities—from sowing to marketing—is crucial for sustaining rural livelihoods, increasing farm productivity, and reducing poverty. The importance of institutional credit has increased over time as traditional informal lending sources have proved exploitative and unsustainable.

Key Challenges:

- Inadequate access to formal credit
- High dependence on informal lenders
- Delay in credit disbursement
- Credit exclusion of tenant farmers and women

Evolution of Agricultural Finance in India

The evolution of agricultural finance can be segmented into key phases:

1. Pre-Independence Era

- Dominated by informal credit sources (moneylenders, traders)
- Exploitative terms, high-interest rates

2. Post-Independence Initiatives

- 1969: Nationalization of banks to boost rural credit
- 1982: Establishment of **NABARD** (National Bank for Agriculture and Rural Development)
- Priority Sector Lending (PSL) guidelines made agricultural lending mandatory for commercial banks

3. Post-1991 Liberalization

- Entry of private banks and microfinance institutions (MFIs)
- Emergence of **Self-Help Groups (SHGs)** and **Joint Liability Groups (JLGs)**
- Kisan Credit Card (KCC) introduced in 1998

Institutional Framework of Agricultural Finance

1. Public Sector Banks

- Largest contributors to agricultural credit (~60%)
- Operate under RBI's priority sector lending norms
- Often face challenges in reaching remote farmers

2. Cooperative Credit Institutions

- Three-tier system: State Cooperative Banks (SCBs), District Central Cooperative Banks (DCCBs), and Primary Agricultural Credit Societies (PACS)
- Significant outreach in rural India but suffer from low capitalization and high NPAs

3. Regional Rural Banks (RRBs)

- Created to provide credit in underserved regions
- Jointly owned by the Central Government, State Government, and sponsoring bank

4. NABARD

- Apex institution for rural credit
- Provides refinance to banks, conducts research, promotes rural infrastructure development

5. Microfinance and SHG-Bank Linkage Programme

- Started in the 1990s to promote financial inclusion
- SHGs have enabled access to credit for women and landless farmers

6. Fintech and Digital Lending Platforms

- Use of mobile apps, AI-based credit scoring, e-KYC
- Digital KCC and Direct Benefit Transfer (DBT) improving transparency

Status of Agricultural Credit in India

1. Growth in Credit Disbursement

Year	Credit to Agriculture (INR Crore)
2015–16	8.77 lakh crore
2020–21	15.75 lakh crore
2023–24 (BE)	20 lakh crore (targeted)

(Source: Ministry of Agriculture & Farmers' Welfare, GoI)

2. Issues in Credit Distribution

- 80% of institutional credit goes to 20% of large farmers
- Small and marginal farmers (86% of total farmers) receive <30%
- Tenant farmers and sharecroppers remain largely excluded due to lack of land records

Government Schemes and Policy Interventions

1. Kisan Credit Card (KCC)

- Provides short-term credit at concessional interest (4% with subvention)
- Over 25 crore KCCs issued till 2023
- New initiative to include livestock and fisheries farmers

2. Interest Subvention Scheme (ISS)

- 2% interest subsidy for timely repayment
- Aims to reduce loan defaults and NPAs

3. Agriculture Infrastructure Fund (AIF)

- INR 1 lakh crore fund for agri-infrastructure development
- Encourages agri-entrepreneurs and FPOs

4. PM-KISAN

- Though not a credit scheme, the INR 6,000 annual income support complements credit requirements

Access Barriers to Agricultural Finance

1. Land Record Issues

- Informal tenancies and joint ownership prevent access to formal credit
- Digitization of land records under Digital India Land Records Modernization Programme (DILRMP) is slow

2. Gender Disparity

- Female farmers hold only 13% of land titles
- Access to credit remains limited for women despite SHG participation

3. Literacy and Documentation

- Low financial literacy and complex paperwork deter farmers
- Lack of awareness of schemes and eligibility

4. Regional Disparities

- Southern states dominate formal credit absorption
- Eastern and Northeastern states lag behind

Role of Technology in Improving Access

1. Jan Dhan–Aadhaar–Mobile (JAM) Trinity

- Enabled DBT and reduced leakages
- Linked with KCC and crop insurance (PMFBY)

2. Digital Lending Apps

- Use of satellite data, AI for farm profiling and credit scoring
- Notable platforms: Samunnati, Jai Kisan, GramCover

3. E-NAM and Digital Marketplaces

- Ensures better price realization, indirectly influencing creditworthiness

Financial Inclusion and Farm Producer Organizations (FPOs)

FPOs have emerged as effective aggregators for smallholders to access:

- Credit
- Insurance
- Inputs
- Markets

Government's plan: Promote 10,000 FPOs by 2027 with financial and technical support.

Recommendations for Improving Agricultural Finance

1. Reform Land Records and Expand KCC

- Promote digitization and legal recognition of tenancy
- Simplify KCC process for marginalized farmers

2. Promote Digital and Mobile Banking

- Expand rural mobile banking and financial literacy
- Encourage innovation through Agri-FinTech startups

3. Strengthen Cooperative Credit Structure

- Refinance and recapitalize PACS
- Improve governance and reduce political interference

4. Gender-Inclusive Credit Policies

- Title land in women's names
- Develop women-specific loan products

5. Credit-Linked Insurance and Infrastructure

- Integrate PMFBY with loans
- Encourage credit for post-harvest storage and processing

Conclusion

Improving agricultural finance is central to rural transformation and the broader goals of food security and inclusive growth in India. While institutions like NABARD, public and private banks, and microfinance initiatives have made significant progress, structural barriers still prevent equitable access to credit. Bridging the rural credit gap demands a combination of technological innovation, inclusive policy frameworks, institutional strengthening, and land reforms. A more diversified, digitized, and demand-responsive agricultural finance ecosystem is essential to empower India's farmers and ensure the sustainability of the agri-food economy.

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INSECT PESTS OF TURMERIC AND THEIR MANAGEMENT

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India is known as the spice bowl of the World, about 63 spices are grown in our country. Spices drawn from various parts of plants like bud, bark, root, flower, and fruits. Turmeric used as spice in curry in Asian food and it has a warm, bitter taste but the root of turmeric is also used widely to make medicine. It contains a yellow-colored chemical called curcumin, which is often used to color foods and cosmetics. Among the various biotic constraints in turmeric (*Curcuma longa* L.) in India, infestation by insects is a crucial one. A number of insect pests are reported like shoot borer, rhizome scale, lacewing bug, thrips, white grub and leaf roller to damage turmeric at different stages of growth.

Shoot borer, *Conogethes punctiferalis* (Crambidae: Lepidoptera)

Identification of the pest

- **Egg:** Eggs are oval and light pink colour laid singly or in group on leaves or other tender parts of the plant. Incubation period lasts 3-4 days.
- **Larva:** The larvae pass through five larval instars with light brown with sparse hairs on fully grown larvae. Larval period last about 2-3 weeks.
- **Pupa:** Pupation takes place in loose silken cocoon in larval tunnel. The pupal stage lasts about 9-10 days.
- **Adult:** Adult are medium size, pale straw colour with numerous black spots on wings. There are 6-7 generations in a year. This pest is most active from July to October.

Nature of damage

The larvae bore into pseudostem and feed on growing parts resulted yellowing and drying of leaves of infested pseudostem which causes 'dead heart'.

Management

- Collection and destruction of the infested shoots
- Use light traps @ 1 /acre for mass trapping and destruction
- Mulching with green *Lantana camara* and *Vitex negundo*
- Use larval parasitoids, *Bracon hebetor* for control of *C. punctiferalis*.
- Use of *Bacillus thuringiensis*.
- Use of EPF like *Metarhizium anisopilae* and *Beauveria bassiana*
- Spray neem oil (0.5%) at fortnightly intervals
- Spray Flubendamide 20 WDG @1 ml/lit or Chlorantraniliprole 18.5SC @1 ml/lit or Cypermethrin 10EC @ 3ml/lit or Quinalphos 25EC@ 2ml/lit during July - October

Rhizome scale, *Aspidiotus hartii* (Diaspididae: Hemiptera)

Identification of the pest

- **Eggs:** Scale reproduce ovoviviparous, eggs are transparent and yellowish in colour. Single female laid about 100 eggs and crawlers are emerge from the eggs.
- **Nymph:** The first stage nymph are active crawlers.

- **Female:** scales are circular with light brown to grey colour and appear as encrustations on the rhizomes.
- **Male:** Male is orange coloured with transparent wings. Male crawlers when fully mature and pupate usually within a day.

Nature of damage

Adult (female) scales feed on sap resulted the rhizomes are severely infested, they become shriveled and affect its germination. When the infestation is severe the rhizome and buds shrivel and ultimately the entire rhizome dries. Rhizome scale infests rhizomes of turmeric both in field and in storage.

Management

- Select healthy rhizomes free from scale infestation for using sowing purpose
- Collect and destroy severely infested rhizomes
- Dip the rhizomes in Malathion (5ml/lit water) solution for 30 minutes and to be dried prior to storage and sowing.
- Application of well rotten sheep manures @ 10 t/ha in 2 splits can control the insect.
- Seed rhizomes are dipped in Phosalone 35 EC@ 1.5 ml/lit for 15 minutes
- Drench soil with phosalone 35 EC @ 2 ml/lit of water

Thrips, *Panchaetothrips indicus* (Thripidae: Thysanoptera)

Identification of the pest

- **Nymph:** Nymphs takes between 7 -12 days to develop into adult thrips
- **Adult:** Thrips are very small, have elongated abdomens, yellowish or blackish in color. They are often found on plants throughout all growth stages, from sprout to tuber maturation

Nature of damage

Thrips damage the undersides of leaves by sucking their plant sap. They damage young and tender parts of plants such as new leaves and shoots. Leaves become rolled up, and turn pale and gradually dry-up.

Management

- Use of resistant varieties
- Selection of healthy planting material
- Removal of weeds
- Use predatory mites for control of thrips
- Spray Methyl demeton 25 EC @850 ml/ha

Bihar hairy caterpillar, *Spilarctia obliqua* (Eribidae: Lepidoptera)

Identification of the pest

- **Egg:** Eggs are laid in clusters on the underside of leaves. Incubation period is 6-9 days
- **Larva:** The larvae are covered with long yellowish to black hairs. Larval period is 34-45 days
- **Pupa:** The pupa forms a thin silken cocoon by interwoven shed hairs of the larvae. Pupal stages lasted within 16- 22 days. Pupation takes place in the soil under dry foliage and debris where the pupae over wintering.
- **Adult:** Medium sized brown moth with red abdomen

Nature of damage

Young caterpillars feed gregariously on leaves and pseudostem resulted defoliation. In severe infestation, the plants dried and easily fall off. After defoliated the crop larvae start feeding on the capsules.

Management

- Collect and destroy the egg masses and larvae
- Remove alternate weed hosts near in and around the field
- Conserve the natural enemies such as ladybird beetle, spiders, dragon fly and praying mantis
- Release *Trichogramma chilonis* @ 20,000/acre
- Spray Emamectin benzoate 5% SG@0.5mg/lt or Chlorantraniliprole 18.5% SC Spray @ 0.5ml/lt

Lacewing bug, *Stephanitis typicus* (Tingidae: Hemiptera)

Identification of the pest

- **Nymphs:** Yellow colour nymphs feed on the foliage
- **Adult:** Small whitish colour bug found in colonies on foliage

Nature of Damage

The foliage of infested plants turns pale or yellow and dries up. Both nymphs and adults feed in colonies on under surface of leaves and cause discolouration.

Management

- Use healthy and pest free rhizomes for planting.
- Apply hot water treatment prior to planting.
- Field release of coccinellid like ladybird and lacewings
- Spray of Phosphamidon 85WSC @300ml/ha

Leaf roller/skipper, *Udaspes folus* (Hesperiidae: Lepidoptera)

Identification of the pest

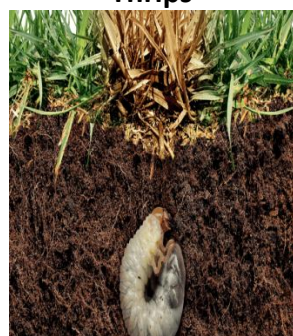
- **Egg:** Pinkish oval flat eggs are laid singly or in groups on leaves. The egg period last for 3-4 days.
- **Larva:** fully grown larvae are dark green colour with five instars. The larval period last for 12-21 days
- **Pupa:** The pupa is long and cylindrical, watery green in colour and pupate inside the leave. The pupal period last for 6-7 days
- **Adult:** Adults are medium sized with brownish black wings with eight white spots on forewings and one large patch on hind wing.

Nature of Damage:

The larvae cut and fold the leaves resulted leaves become folded or rolled longitudinally. The young larvae start scrapping later web together nearby leaves, leaving behind the papery epidermis and complete defoliation.

Management

- Hand pick and destroy the larvae and pupae to reduce the intensity of the pest
- Spray Phosphamidon 85 WSC @300 ml/ha or Carbaryl 50 WP @ 1000 g/ha

**Shoot borer****Rhizome scale****Thrips****Bihar hairy caterpillar****Lacewing bug****Skipper****White grub****Leaf beetle****White grub, *Holotrichia consanguinea* (Scarabaeidae: Coleoptera)****Identification of the pest**

- **Egg:** The females lay eggs in soil. The eggs are white, almost round in shape. Incubation period is 8-10 days.
- **Grub:** Grubs are 'C' shaped, slow movers having globular head and elongated, dorsoventrally flattened body. The young grubs are white translucent, whereas mature grubs are pale in colour. Grub period lasts 56-70 days.
- **Pupa:** Pupation takes place in soil. Pupal period lasts 12-16 days.
- **Adult:** Adults of white grub are about 18-20 mm long and 7-9 mm wide and having single generation per year.

Nature of Damage

Grubs and adults both are damaging stage. The grubs live in soil and remain active, feed on the functional roots of the plant, leaving behind only tap root. They also burrow into the pseudostem, close to the soil surface and kill the plant. Grub infested plants turn pale, leaves and branches drop down, the plant withers and can be easily uprooted. It ultimately dies off resulting in patchy crop growth. Root grubs occasionally feed on tender rhizomes, roots and base of pseudostem causing yellowing and wilting of shoots.

Management

- Use of light trap @ 1 trap/ha
- Drench the root zone of crop with Chlorpyrifos 20EC @2.5lt/ha or Quinalphos 25EC @ 2lt/ha after the adult emergence
- Spray any of the following insecticides, Clothianidin 50 WDG @ 250 gm/ha or Chlorantraniliprole 18.5 SC@625 ml/ha

Leaf beetle/Flea beetle: *Lema praeusta*, (Chrysomelidae: Coleoptera)

Identification of the pest

- **Egg**- eggs laid singly on leaves. Incubation period is 8-10 days
- **Grub**- grubs feeding on leaf tissue Adults emerged after 15-25 days.
- **Pupa**: pupa pupates in the soil.
- **Adult**-Adults are small, elliptical or oval shaped, dark or metallic in colour

Nature of damage : Both adults and grubs feed on leaf and characteristic shot holes appear on the leaves.

Management

- Removal of weeds and plant debris
- Use of white and yellow sticky traps
- Use foliar spray of neem solution application as repellants
- Use predators like *Chrysopa carnea* and *Gryllus* spp.
- Dusting carbaryl 10 D @25 kg/ha

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ENHANCING INDOOR SPACES WITH INTERIOR LANDSCAPING

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Abstract

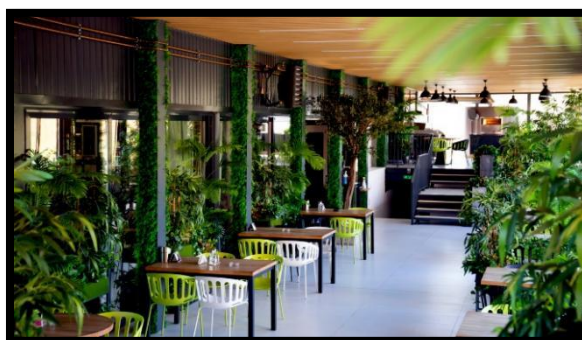
The Studies indicate that poor indoor air quality causes approximately 3.8 million premature deaths annually, with major contributors being pneumonia (27%), stroke (18%), ischemic heart disease (27%), COPD (20%), and lung cancer (8%). NASA recommends 15–18 plants in 6–8-inch containers to purify the air in an 1,800 sq. ft. home, ensuring healthier indoor environments. Poor ventilation traps pollutants, leading to various health concerns. One of the key benefits of biophilic indoor design is improved air quality. The plants act as natural air purifiers, removing toxins and releasing oxygen, making indoor spaces fresher and healthier. Studies show that greenery also reduces stress, enhances well-being, and fosters a calming atmosphere. In office settings, plants can boost productivity, creativity, and concentration. As industrialization and corporate lifestyles dominate the 21st century, air pollution and stress have become critical concerns. Integrating indoor plants offers a simple yet effective way to counter these challenges, promoting healthier and more sustainable living and working environments.

Keywords: Indoor plants, Biophilic design, Air purification, Health benefits, Sustainable living

Introduction

The interior landscaping is the art of designing, installing, and minding for shops in an enclosed terrain. Interior landscaping creates an overall affable terrain by using natural colours, focal points, beautifiers, and sculptural rudiments. The inner space is “landscaped” by adding shops and agronomists to soften the angles of the room or to accentuate an architectural point. Landscaping is a word that utmost likely makes you suppose of the outside. The possibilities with interior landscaping are endless. Indoor landscaping, also known as “factory scaping” or “interior scaping” does the same thing. In 1989 NASA Clean Air Study, led by Dr. B.C. Wolverton, delved the eventuality of inner shops to remove unpredictable organic composites (VOCs) from inner air. The study tested colourful common inner shops for their capability to remove adulterants similar as benzene, formaldehyde, and trichloroethylene. The findings suggested that certain shops could effectively reduce situations of these VOCs in sealed surroundings. analogous to the great outside, inner surroundings have plains, angles and midair’s that can be altered or enhanced to come a true work

of art. Interior scaping can greatly enhance the visual appeal of any inner space. The lush, vibrant colours of shops and the variety of textures they offer can transfigure a dull and sterile terrain into a drinking and inviting one. Inner shops can also act as natural sound absorbers, reducing background noise and creating a quieter and more peaceful atmosphere. shops can help regulate inner temperatures by furnishing shade and releasing humidity into the air, leading to energy savings and increased comfort. For businesses, Interior scaping can help ameliorate their brand image by creating a positive and eco-friendly print on guests and guests. Inner shops bear regular care and conservation, including watering, pruning, and pest control. Without proper attention, shops can come unhealthy and abstract from the asked air. Some inner spaces may warrant acceptable natural light, making it challenging to grow certain shops. In similar cases, artificial lighting results may be necessary to support factory growth. In small or crowded spaces, it can be gruelling to incorporate expansive Interior scaping without compromising functionality. Planning duly and coming up with original design ideas are pivotal. High- quality shops and holders, along with conservation costs, can add up. Businesses and individualities should budget consequently to insure the long- term success of their Interior scaping systems.



Principles of Interior scaping:

Factors such as light levels, temperature, humidity, and air circulation will determine the types of plants that can thrive in the space. Choose plants that are well-suited to the indoor environment. Low-light plants like snake plants and pothos are ideal for spaces with limited natural light, while succulents and cacti thrive in drier conditions. The choice of containers or pots is an important design element. Containers should complement the overall aesthetic of the space and provide adequate drainage for the plants. Consider the placement and arrangement of plants within the space. Grouping plants with similar light and water requirements can simplify maintenance and create visually appealing displays. Developing a maintenance plan is crucial to ensure the long-term health and vitality of the indoor landscape. This includes watering, pruning, fertilizing, and monitoring for pests and diseases. Pay attention to the aesthetics of the space. The future of Interior scaping holds exciting possibilities. Advancements in technology, such as automated irrigation systems and LED grow lights, will make it easier to maintain indoor landscapes.

Scientific Principles in Interior Landscaping:

➤ Air Purification and VOC Absorption

Studies (Wolverton et al., 1989) indicate that plants such as *Sansevieria trifasciata* (Snake Plant) and *Spathiphyllum wallisii* (Peace Lily) effectively absorb volatile organic compounds (VOCs) like formaldehyde, benzene, and toluene.

NASA's Clean Air Study recommends placing at least one plant per 10m² for optimal indoor air filtration.

➤ **Photosynthesis Efficiency & Light Adaptation**

Low-light tolerant plants like *Epipremnum aureum* (Pothos) and *Aglaonema* spp. (Chinese Evergreen) thrive in dimly lit spaces due to their C3 photosynthetic pathway.

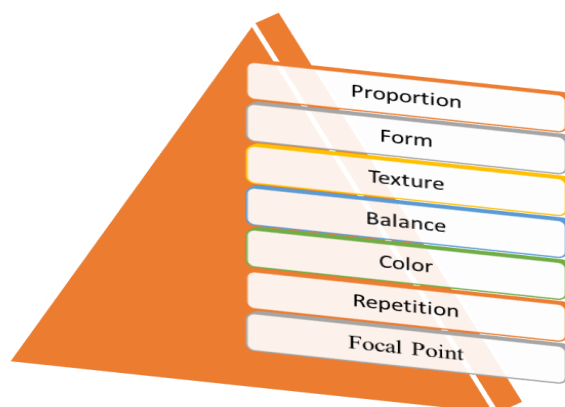
Plants requiring bright light, such as *Ficus benjamina* (Weeping Fig), should be placed near windows or under artificial grow lights (LEDs with specific wavelengths for photosynthesis optimization).

➤ **Microclimate Regulation and Humidity Control**

Transpiration from plants like Areca Palm (*Dyopsis lutescens*) and *Nephrolepis exaltata* (Boston Fern) increases humidity levels, reducing dry air issues in homes.

A balanced plant ecosystem mitigates indoor temperature fluctuations by regulating heat absorption and moisture release.

ELEMENTS OF INTERIOR LANDSCAPE



BENEFITS OF INDOOR LANDSCAPING

Indoor plants are the most efficient and cost-effective means of removing air pollution, two plants per 100 sq. ft or two plants per a small office keep the air pure and healthy plant. Psychological impact of plants in shopping environment - The urban forest is an essential component of any viable retail space Interior Plantscape helps to create powerful business image Aside from creating beautiful sites, indoor landscaping provides physical and mental health benefits. The reason plants and trees are important to our ecosystem is because they remove carbon dioxide and produce oxygen rich air. Adding plant scapes to your interior enhances your indoor air quality by removing toxins and filtering air. Additionally, plants can save energy by increasing humidity and keeping the air temperature down. There are some benefits of interior scaping which are given below:

- 1) **Organic production** : organic plants and their products can be easily accessible as indoor plants are safe from pests and weeds.
- 2) **Economically beneficial** : Very less financial backup is needed to grow and take care of indoor plants. Can help in reducing the grocery bill as well as money spent on herbs.
- 3) **Gardening as a therapy** : this exercise brings peace to our soul and enhances brain activity.
- 4) **Air Quality enhancement** : Increased oxygen level results in oxygen rich blood which further improves concentration and healthy mind.

- 4) **Eco-friendly** : It contributes in maintaining the sustainability of our planet. Decrease in the air pollution and less intake of polluted substances.
- 5) **Aesthetic appeal** : the plants help in reduction of background noise and create a tranquil environment. They help to reduce stress and tension which results in better mental well-being.
- 6) **Symbolic and emotional** : Carries a person to naturalistic environment as well as mentally and emotionally maintains a person's contact with nature.
- 7) **Architectural** : It defines space and helps in maintaining privacy from unpleasant views.

PLANTS ORGANIZATION IN A PLACE:

There are no rules to decorate a place with plants, it's a matter of personal choice. The grouping can be done on the basis of the required aspects of the plants as noise absorbing plants must be used at a working place where background noise is constant. Herbal plants can be used at homes as their products will be available for kitchen use as well. Air purifying plants can be beneficial at both the work places and the homes.

Indoor Plant Arrangement Strategies:

- The placement of plants should cater to their functional benefits:
- **Noise-absorbing plants**: Ideal for workspaces to reduce background noise.
- **Herbal plants**: Suitable for homes, providing fresh ingredients for cooking.
- **Air-purifying plants**: Essential in both homes and offices to improve air quality.
- Following table shows the sound frequency absorption by different plants:

Sound frequency

Plant species	125Hz	250Hz	500Hz	1KHz	2KHz	4KHz
<i>Dracaena marginata</i>	0.13	0.03	0.16	0.08	0.14	0.47
<i>Schefflera arboricola</i>	-	0.13	0.06	0.22	0.23	0.47
<i>Ficus benjamina</i>	0.06	0.06	0.10	0.19	0.22	0.57
<i>Spathiphyllum wallisii</i>	0.09	0.07	0.08	0.13	0.22	0.57
<i>Dracaena fragrans</i>	0.13	0.14	0.12	0.12	0.16	0.11
<i>Howea forsteriana</i>	0.21	0.11	0.09	0.22	0.11	0.08

Air Pollutant Removal by Plants over 24 hours

Research by Wolverton *et al.*, (1989) highlights the air-purifying properties of indoor plants. Two plants per 100 sq. ft. are sufficient to maintain healthy air quality.



BEST SUITED INDOOR PLANTS AS PER INDIAN SUBCONTINENT

Common name	Botanical name	Usage
Snake plant	<i>Dracaena trifasciata</i>	Absorbs various VOCs
Spider plant	<i>Chlorophytum comosum</i>	Eliminate xylene and formaldehyde
Lucky bamboo	<i>Dracaena sanderiana</i>	Aesthetic pleasure
Weeping fig	<i>Ficus benjamina</i>	Clears xylene
Areca palm	<i>Dypsis lutescens</i>	Absorbs formaldehyde
Boston fern	<i>Nephrolepis exaltata</i>	Sucks toxic VOCs
Baby rubber plant	<i>Peperomia obtusifolia</i>	Flowers helps in distress
Pothos	<i>Epipremnum aureum</i>	Absorbs xylene, toluene, benzene
Flamingo lily	<i>Anthurium andraeanum</i>	Reduces ammonia conc
Grape ivy	<i>Cissus rhombifolia Vahl</i>	Maintains oxygen level
Croton	<i>Codiaeum variegatum</i>	Colors soothe mind

Main objectives of using indoor plants at different places

- Interior plants lower O&M (Operations and Maintenance) costs while contributing to green building.
- Plants in the workplace attract, retain and enhance attitude of today's selective employee.
- The dramatic aesthetic value inherent in indoor landscaping has continued to be the number one return on interior plant investments.
- It's finally possible to have an energy efficient building without "Sick Building Syndrome" Plants help with bottom line savings on mounting sick leave expenses.
- Plants help reduce distractions due to office noise.

Future of Interior Landscaping

Technological advancements such as automated irrigation systems and LED grow lights will simplify plant maintenance, making indoor landscaping more accessible and efficient.

Conclusion

Interior landscaping plays a crucial role in enhancing indoor air quality, reducing stress, and promoting overall well-being. Whether in homes or workplaces, strategic plant placement can create a healthier and more aesthetically pleasing environment. The future of indoor landscaping looks promising with the integration of smart technologies, paving the way for greener and more sustainable indoor spaces.

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INDIA'S AGRICULTURAL POST-HARVEST LOSSES: AN ECONOMIC ANALYSIS

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Abstract

Post-harvest losses in Indian agriculture represent a significant drain on the economy, food security, and farmer livelihoods. This article explores the causes, magnitude, and economic impacts of these losses, analyzes existing policies and technologies to mitigate them, and discusses future pathways to reduce losses and improve agricultural value chains.

Introduction

Agriculture is the backbone of India's economy, contributing approximately 17-18% to the GDP and employing more than 50% of the workforce (GOI, 2021). Despite India's remarkable progress in food production, nearly one-third of agricultural produce is lost after harvest due to inadequate storage, transportation, and processing infrastructure (FAO, 2019). Post-harvest losses (PHLs) reduce farmer income, increase food prices, and hamper efforts toward food security and sustainable development.

Definition : Post-harvest loss refers to the measurable quantitative and qualitative loss of agricultural produce during harvesting, handling, storage, processing, packaging, and marketing (Kumar *et al.*, 2020).

Magnitude and Types of Post-Harvest Losses in India

1. Estimated Scale

- According to the Indian Council of Agricultural Research (ICAR), PHL ranges between 15% to 30% for perishables such as fruits and vegetables, and about 6-10% for cereals and pulses (ICAR, 2018).
- The National Institute of Agricultural Marketing (NIAM) estimates losses worth around INR 92,000 crore annually (NIAM, 2019).

2. Commodity-wise Losses

- Fruits & Vegetables: 20-30%
- Cereals: 6-10%
- Pulses & Oilseeds: 5-7%
- Spices: 2-5%
- Fish and Meat: 10-15%

3. Stages of Loss

Losses occur at multiple points:

- Harvesting: improper techniques causing mechanical damage

- Handling & Transportation: poor packaging, rough handling, and long distances without refrigeration
- Storage: insect infestation, fungal contamination, and inadequate storage facilities
- Processing & Marketing: lack of processing units and inefficient markets

Causes of Post-Harvest Losses in India

1. Infrastructure Deficiency

- Lack of adequate cold storage facilities (only about 40 million tonnes capacity against 68 million tonnes production of perishables) (NHB, 2020).
- Poor rural roads and transportation systems causing delays and damage.

2. Technological Limitations

- Traditional harvesting and handling methods lead to mechanical injuries to produce.
- Limited adoption of modern packaging and preservation technologies.

3. Institutional and Market Constraints

- Fragmented supply chains with many intermediaries, reducing incentives for quality maintenance.
- Insufficient market intelligence and price information for farmers.

4. Climatic and Biological Factors

- High temperature and humidity promote microbial growth.
- Pest and disease infestation due to poor pest management.

Economic Impacts of Post-Harvest Losses

1. Loss to Farmers' Income : PHLs directly reduce the quantity of saleable produce, depressing farmer incomes and exacerbating rural poverty (Pingali, 2015).

2. Impact on Food Prices and Inflation : Reduced supply due to losses can cause price volatility, affecting consumers, especially the poor (World Bank, 2019).

3. National Economic Burden : Losses undermine GDP contribution from agriculture and increase food import dependency. The economic loss from PHLs is estimated to be around 10% of the agricultural GDP (GOI, 2021).

4. Wastage of Resources : Water, land, energy, and labor invested in production go wasted due to losses, affecting environmental sustainability (FAO, 2013).

Policies and Institutional Measures to Reduce Losses

1. Government Schemes

- **Operation Greens:** Focuses on reducing losses in tomato, onion, and potato supply chains by improving processing and storage infrastructure (GOI, 2018).
- **PM Kisan Sampada Yojana:** Promotes agro-processing clusters and cold chain infrastructure (GOI, 2020).

2. Agricultural Marketing Reforms

- Implementation of electronic National Agriculture Market (e-NAM) to improve price discovery and reduce intermediaries.

3. Public-Private Partnerships

- Encouraging private investments in cold chains, warehouses, and pack houses.

Technological Innovations and Solutions

1. Cold Chain Technologies

- Use of refrigerated transport, cold storage, and controlled atmosphere storage to extend shelf life.

2. Improved Packaging

- Modified atmosphere packaging, vacuum packaging, and biodegradable materials.

3. Digital Technologies

- IoT-enabled monitoring of storage conditions, AI for supply chain optimization.

4. Training and Capacity Building

- Farmer education on best harvesting and handling practices.

Case Studies

1. Successful Reduction of PHL in Mango Supply Chain

Introduction of cold storage and pre-cooling units in Andhra Pradesh reduced losses by 15% and increased farmer profits (Reddy et al., 2019).

2. Integrated Post-Harvest Management in Punjab

Implementation of community storage facilities and market linkages resulted in 20% reduction in losses for wheat and vegetables (Singh et al., 2020).

Challenges and Future Directions

- Scaling up infrastructure investments.
- Encouraging adoption of modern technologies among smallholders.
- Strengthening institutional frameworks and credit availability.
- Integrating climate resilience in post-harvest systems.

Conclusion

Post-harvest losses pose a serious economic challenge to India's agriculture, affecting food security and farmer welfare. A coordinated approach involving infrastructure development, technological innovation, policy support, and capacity building is critical to minimize these losses. Reducing PHLs will enhance agricultural efficiency, stabilize food prices, and improve incomes, contributing to sustainable rural development.

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IoT IN AGRICULTURE: CHALLENGES FOR EXTENSION IN UPSKILLING FIELD STAFF

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Abstract

The integration of IoT in agriculture offers great potential but poses challenges for extension systems, especially in upskilling field staff. Many lack the technical skills, digital literacy, and training needed to support IoT adoption. Barriers include limited resources, resistance to change, and the need for continuous learning. The importance of targeted capacity-building, cross-sector collaboration, and supportive policies to empower extension personnel and ensure their effective role in advancing smart agriculture.

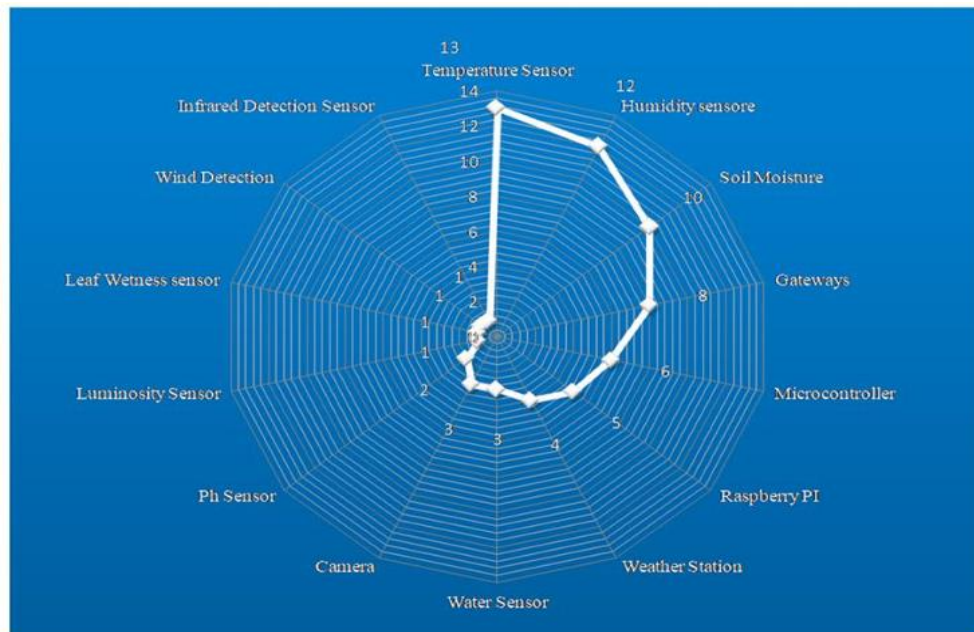
Keywords : Internet of Things (IoT), Smart Agriculture, Agricultural Extension, Field Staff Training

Introduction

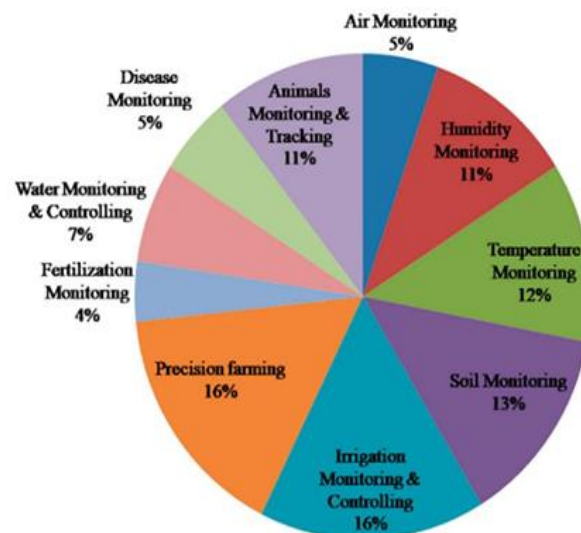
The Internet of Things (IoT) is revolutionizing agriculture through smart tools like precision irrigation and climate forecasting, improving productivity and sustainability. Extension systems are vital in linking technology developers with farmers, but many extension workers lack the digital skills needed for IoT due to traditional training. Challenges such as low digital literacy, limited access to tools, weak infrastructure, and resistance to change hinder adoption. Continuous learning is essential to keep pace with evolving technology. Strengthening IoT adoption requires collaborative capacity-building efforts involving public institutions, private tech companies, and academia, supported by robust policies and digital infrastructure.

Focus of Each IoT Agricultural Application

IoT applications in agriculture mainly focus on monitoring, control, and tracking. As per Farooq et al., (2020), key functions include irrigation and precision farming (16% each), soil monitoring (13%), temperature (12%), humidity (11%), livestock tracking (11%), water management (7%), disease monitoring (5%), air quality (5%), and fertilizer use (4%). These uses highlight IoT's role in optimizing diverse farm activities. Innovative IoT technologies are transforming agriculture by monitoring essential parameters. Systems like ZigBee and solar-powered sensors track air quality, humidity, and temperature, while wireless sensors measure soil moisture and temperature for improved farm management (Nguyen et al., 2022). Water quality tools assess pH, temperature, and chemical content (Mowla et al., 2023). The LOFAR-agro Project aids in protecting potato crops by monitoring climate conditions (Aldossary et al., 2024). IoT also supports crop and vineyard monitoring, greenhouse gas detection via drones, and automated greenhouse operations. Additionally, livestock trackers help prevent crop damage and theft.



Agricultural applications of IoT (Farooq et al., 2020)



Role of IoT-Based Sensors in Agriculture

IoT devices in agriculture utilize embedded systems with sensors, actuators, and wireless networks to gather real-time data, enhancing farm management. These sensors monitor temperature, humidity, soil moisture, and air flow, enabling smart farming. Farooq *et al.*, (2020) associate such technologies with Agriculture 5.0. Mowla et al., (2023) highlight features like portability, reliability, energy efficiency, and broad coverage, making IoT sensors well-suited for challenging agricultural environments.

Sensor distribution in IoT-based agriculture

Research trends show that most studies focus on monitoring temperature (19%), humidity (17%), and soil moisture (14%), with over 20 types of agricultural data collected using IoT sensors. These findings highlight the vital role of IoT in precision agriculture and data-driven farm optimization.

Role of IoT Communication Protocols and Standards in Agriculture

IoT communication protocols are crucial in smart agriculture for seamless data exchange among devices. Wireless Sensor Networks (29%) lead usage, followed by Wi-Fi (15%) and ZigBee (10%). Protocols like LoRaWAN support long-range, low-power communication, while MQTT aids real-time irrigation data. RFID tracks crops and the environment, SigFox monitors livestock, and ZigBee ensures reliable low-power data transfer. Wi-Fi enables internet access in hybrid systems, Bluetooth suits small farms, and WiMAX supports long-range tasks like field surveillance and remote diagnostics.

Challenges in Upskilling Field Staff for IoT in Agriculture

Upskilling agricultural field staff for IoT faces hurdles like low digital literacy, poor training infrastructure, and reluctance to adopt new technologies. Many extension workers are rooted in traditional methods, making it hard to grasp IoT systems and data use. Limited internet access, lack of technical support in rural areas, and budget limitations further slow progress. The absence of customized learning modules adds to the challenge. Overcoming these issues is vital to unlock the full benefits of IoT in agriculture.

Future Prospects for Upskilling Extension Staff in IoT-Based Agriculture

The future of upskilling extension staff in IoT-based agriculture depends on accessible, continuous learning. As digital tools grow in farming, extension workers need skills in IoT, data use, and digital advisories. Tailored training, e-learning, and public-private efforts are vital to build capacity. Integrating IoT into curricula, using mobile tools, and promoting local content will boost impact. Ongoing capacity-building can make extension services more responsive, data-driven, and effective in advancing smart agriculture.

Conclusion

Integrating IoT in agriculture can boost productivity and sustainability, but extension services are key to supporting farmers during this digital shift. A major challenge is the limited digital skills of field staff, compounded by poor infrastructure and resistance to change. Addressing these through targeted training, supportive policies, and human resource investment is crucial. Empowering extension personnel with digital competencies will ensure effective, timely advisory services and help build a resilient, technology-driven agricultural ecosystem.

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EFFECT OF PESTICIDES ON SOIL MICROBIAL ACTIVITY

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Abstract

Pesticides are widely used for pest control, but significantly it impacts on soil health by altering microbial diversity, enzymatic activity and key biochemical processes. While, some soil microbes can degrade pesticides and pesticides also inhibit growth, disrupt metabolism, and reduce enzyme activity of microorganisms. Pesticides can suppress beneficial rhizospheric microorganisms, interfere with nitrogen fixation and inhibit the decomposition of organic matter, thereby affecting nutrient cycling. Enzymes such as nitrogenase, dehydrogenase, urease, and phosphatase serve as sensitive indicators of pesticide-induced stress, often showing variable activity depending on soil type, pesticide concentration and exposure duration. Although some pesticides may temporarily stimulate microbial functions, their long-term use can disrupt soil microbial equilibrium, reducing fertility and productivity. Therefore, sustainable pesticide management is crucial for preserving soil ecosystem health.

Keywords: Pesticides, soil, microbial activity, enzymes

Introduction

Pesticide means any substance intended for preventing, destroying, attracting, repelling or controlling any pest including unwanted species of plants.

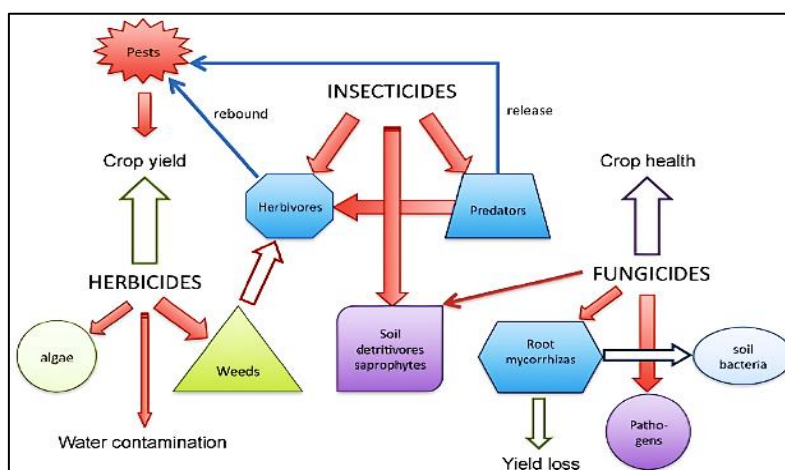


Fig. 1: Impacts of pesticides on soil, plant and arthropod communities
(Red arrows indicate decreases and blue arrows indicate increases; empty arrows indicate indirect effects. Sánchez-Bayo, 2011)

Synthetic pesticides, though essential for pest control, can negatively impact non-target organisms, including microbes that live in the soil. They are known to hinder microbial growth, impair important biochemical reactions like nitrogen fixation and reduce key soil enzyme functions. This summary provides insight into how pesticides influence soil microbial diversity, enzymatic activity and essential biochemical reactions vital for soil health and productivity.

Effect on Soil Microbial Diversity

Once applied to soil, pesticides undergo various processes such as degradation, transportation and adsorption or desorption, influenced by both their chemical nature and soil characteristics. These chemicals can interfere with soil microbial metabolism, altering their physiological and biochemical functions. Microbial biomass, a key indicator of soil activity and nutrient cycling, is often reduced by pesticide exposure. Certain pesticides may suppress or eliminate specific microbial groups, allowing others to dominate. For example, fungicides may inhibit fungi, resulting in a temporary increase in bacterial populations. Additionally, herbicides and bactericides can reduce beneficial rhizospheric microbes, negatively impacting plant growth and soil health. This phenomenon disrupts the soil-microbial equilibrium and soil microbial biodiversity.

Impact on Microbial Factor

The impact of pesticides on soil microorganisms is influenced by several environmental factors, including the chemical's persistence, bio-accumulation, toxicity and especially its bioavailability. Bioavailability, governed by adsorption and desorption dynamics, determines a pesticide's concentration in soil solution and affects its biological activity and degradation. Several other soil parameters such as texture, organic matter content and vegetation, also play significant roles in moderating pesticide toxicity. Additionally, supplementing soils with carbon sources like glucose, acetate and amino acids such as glutamine, arginine, serine and tryptophan has been shown to improve fungal resistance to pesticide-induced stress (Mishra and Pandey, 1989).

1. Root-colonizing microbes

Beneficial root-associated microbes, including bacteria and arbuscular mycorrhizal (AM) fungi, form symbiotic relationships with most plants, enhancing their growth and resilience under both normal and stressful conditions. However, external pesticide applications can disrupt their functions. For example, although Hexachlorocyclohexane (HCH) had little impact on AM colonization in *Plantago* roots, it significantly reduced AM spore density and viable hyphae in contaminated soils (Sainz *et al.*, 2006). Similarly, anthracene application was found to reduce sporulation, root colonization and spore germination activities in root colonizing fungi. Fox *et al.* (2007) also reported that some organochlorine pesticides delayed rhizobial colonization, reduced nodule formation and nitrogenase activity and ultimately decreased crop yield.

2. Nitrogen transformation in soil

Biological nitrogen fixation (BNF) serves as a highly efficient and natural mechanism for adding plant available nitrogen into ecosystems. Different estimates suggest that BNF contributes nearly twice the nitrogen compared to non-biological methods. However, pesticides can negatively impact this process, particularly in legumes, by interfering with the virulence of nodulating bacteria or disrupting root structures where infection and nodulation occur.

Organic matter is a vital component of soil that significantly influences its fertility, quality and the release of trace gases into the atmosphere. The transformation and stability of organic matter are largely governed by microbial activities and the nature of plant residues returned to the soil. Studies

have shown that pesticide use can inhibit the decomposition and mineralization of organic matter across diverse ecosystems, including farmlands, grasslands, forests and deserts.

Conversely, some research indicates that pesticides can enhance mineralization processes. This positive effect may arise from the microbial breakdown of insecticides, which promotes the proliferation and metabolic activity of heterotrophic microbes. These microbes accelerate the transformation of organic matter and plant nutrients, using them as sources of energy and essential elements for cell function. As a result, there may be a reduction in the retention of organic carbon in the soil. Additionally, insecticides may boost the growth of ammonifying and nitrifying bacteria, which are primarily responsible for converting organic nitrogen into plant-available forms.

Pesticides also influence other key biochemical processes such as nitrification, denitrification and ammonification by altering the activity of microbial communities involved in these cycles. While, some pesticides may stimulate these processes, they can also inhibit the production of crucial trace gases like nitrous oxide (N₂O) and nitric oxide (NO), even at low concentrations. For instance, lindane, captan and malathion suppressed nitrification and phosphate solubilization in tropical soils, with only malathion enhancing sulphur oxidation (Ogunseitan and Odeyemi, 1985).

3. Effect of Pesticides on Soil Enzymes

Soil harbours a wide array of enzymes, including those that are free, bound to soil particles, or located within microbial cells. These enzymes are crucial indicators of the soil's biological stability, fertility and quality and they can signal ecological changes resulting from environmental pollution. The activity and function of soil enzymes are influenced by their interactions with the soil matrix and external stressors like acid rain, heavy metals, pesticides and industrial pollutants. When pesticides enter the soil, they can disrupt microbial metabolism and enzymatic activity.

Pesticides have damaging effects on soil enzymes such as dehydrogenases, hydrolases and oxidoreductases. However, some pesticides have also been shown to enhance enzyme activities and ATP levels in soil. Since, ATP content correlates with certain enzymatic functions, it can serve as a useful marker for assessing the transformation and fate of pesticides in the soil environment. The contrasting effects of pesticides on enzyme activity depend on multiple factors, including the chemical nature and concentration of the pesticide, the composition of the soil microbial community and the physicochemical characteristics of the soil.

Soil enzyme activity encompasses contributions from enzymes present in the soil solution, those associated with microbial life and those adsorbed onto soil colloids and humic substances. These activities are further modulated by soil moisture, temperature and organic matter content. The complexity and variability of the soil environment, along with the diverse roles and behaviours of extracellular enzymes, make it challenging to clearly interpret the influence of pesticides on these enzymes, especially in natural soil systems (Hussain *et al.*, 2009).

• Nitrogenase enzyme

Nitrogenase is an essential enzyme for the fixation of atmospheric nitrogen (N₂) by different nitrogen fixing organisms. The application of pesticides can negatively impact the activity and efficiency of this enzyme. Several studies have shown that pesticides adversely affect nitrogenase activity in nitrogen-fixing bacteria, including purple non-sulphur bacteria, methylophs and cyanobacteria. Conversely, repeated pesticide applications have sometimes been found to enhance nitrogenase activity in the rhizosphere.

- **Dehydrogenase enzyme**

Dehydrogenases are intracellular enzymes found in all living microbial cells and are closely associated with microbial respiration. Their activity in soil serves as a reliable indicator of overall microbial functioning. Studies examining the impact of the organophosphate insecticide quinalphos revealed a 30 per cent ($p < 0.05$) reduction in dehydrogenase activity (DHA) within 15 days of application. However, DHA levels were restored after 90 days, likely due to microbial adaptation to chemical stress under challenging conditions (Menon *et al.*, 2005). Similar trends have been observed with the application of various insecticides, fungicides, herbicides and soil fumigants.

- **Urease and phosphatase enzymes**

Hydrolases play a vital role in soil nutrient cycling, particularly involving nitrogen, phosphorus, carbon and sulphur. Among them, urease is crucial in the nitrogen cycle as it catalyzes the conversion of urea into carbon dioxide (CO_2) and ammonia (NH_3). This enzyme is widely present in various soil bacteria and fungi. Phosphatase, another key enzyme, is produced extracellularly by many soil microorganisms and facilitates the breakdown of organic phosphorus compounds into inorganic forms. Studies have shown that pesticide applications can lead to varied effects on urease activity, ranging from no change to either an increase or a decrease.

The level of urease activity is often linked to the microbial population size and its metabolic activity. In agricultural soils, urease-mediated hydrolysis of applied urea—a common nitrogen fertilizer—produces ammonium ions (NH_4^+), which are readily absorbed by plants. However, these ions can be quickly transformed into nitrate (NO_3^-) through nitrification and nitrate is prone to leaching with water. Reduced urease activity following pesticide exposure can be advantageous, as it slows urea breakdown and helps retain nitrogen in the ammonium form (NH_4^+), which is less susceptible to leaching losses (Antonious, 2003).

- **β -Glucosidase, cellulase, invertase and other enzymes**

Enzymes such as β -glucosidase, cellulase and invertase play vital roles in the breakdown and transformation of organic matter in soil. β -glucosidase facilitates the hydrolysis of disaccharides, producing β -glucose, which serves as a key energy source for soil microbes. Cellulase breaks down cellulose, a primary structural polysaccharide in plant cell walls into D-glucose, contributing significantly to organic matter input in soils. Another widely distributed soil enzyme, invertase, catalyzes the conversion of sucrose into glucose and fructose. Additionally, enzymes like nitrate reductase, arylsulfatase, amylase, xylanase, catalase and protease are essential for driving various biochemical reactions and sustaining nutrient cycling in soil ecosystems.

The impact of pesticides on these enzyme activities can vary, showing increases, decreases, or no change at all, based on several factors. These include the type and concentration of the pesticide applied, the duration of exposure (incubation period), the existing level of enzyme activity in the soil and overall soil conditions.

Conclusion

Although certain pesticides can act as carbon or energy sources for soil microorganisms and be degraded by them. The impacts vary greatly depending on pesticide type, concentration, soil properties and microbial resilience. These variations make it difficult to draw universal conclusions regarding pesticide effects on soil ecosystems. Long-term use of pesticides can disrupt biochemical equilibrium, lowering soil fertility and productivity. To improve risk assessments and management

strategies, future research should prioritize molecular-level studies over traditional approaches to gain deeper insight into pesticide-induced changes in soil biology and biochemistry.

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KOKUM - A FUNCTIONAL FOOD FROM INDIA'S WESTERN GHATS

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Abstract

Kokum (*Garcinia indica*), a vibrant fruit native to India's Western Ghats, is gaining recognition as a functional food due to its unique blend of nutritional and medicinal properties. Traditionally used in regional cuisines and Ayurveda for its cooling and digestive benefits, kokum is rich in bioactive compounds like hydroxycitric acid, garcinol, and anthocyanins. These contribute to its antioxidant, anti-inflammatory, and lipid-lowering effects. As scientific research validates its therapeutic potential, kokum is emerging in modern nutraceuticals, health foods, and cosmetics. Its sustainable cultivation, low ecological footprint, and role in supporting rural livelihoods add further value. With rising global interest in plant-based wellness, kokum holds promise as a climate-resilient superfruit that bridges traditional knowledge and contemporary health trends.

Keywords: Kokum, Functional food, Hydroxycitric acid, Western Ghats, Antioxidants

Introduction

Kokum (*Garcinia indica*) is a vibrant purple fruit native to the Western Ghats of India. Although relatively unknown outside of its native region, kokum has long held an esteemed place in traditional kitchens and folk medicine for its refreshing taste and therapeutic properties. With growing global interest in plant-based and functional foods those that provide health benefits beyond basic nutrition kokum is now drawing attention from researchers, health-conscious consumers, and food innovators alike. Known for its tangy taste and cooling properties, kokum is often consumed as a juice or added to curries and dals. But it is more than a culinary ingredient. Kokum contains potent bioactive compounds that aid digestion, fight inflammation, and protect against oxidative stress. Its rind is rich in anthocyanins and garcinol, compounds increasingly studied for their antioxidant and anti-cancer potential. This article explores kokum's transformation from a humble forest fruit to a rising functional food star. From its roots in the biodiverse hills of the Western Ghats to its promise as a nutraceutical ingredient, kokum represents a perfect example of how traditional knowledge aligns with modern science. As we journey through its origins, nutritional benefits, cultural relevance, and potential in the wellness industry, kokum emerges as a food of the future, deeply rooted in the past.

The Western Ghats: Kokum's Natural Home

The Western Ghats, a UNESCO World Heritage Site and one of the world's eight "hottest hotspots" of biodiversity, stretch along the western edge of India. This lush mountain range is home to

countless endemic species, including kokum (*Garcinia indica*). Flourishing in the warm, humid climate and lateritic soils of the region, kokum trees are typically found in forest clearings, backyard orchards, and agroforestry systems. Kokum trees are hardy and drought-tolerant, thriving without the need for chemical fertilizers or intensive care. This makes them ideal for sustainable farming and reforestation projects. In the wild, kokum contributes to the local ecosystem by supporting biodiversity and maintaining soil health. The tree blooms in the early summer and bears small, round, red-to-purple fruits that are harvested between April and June.



Fresh kokum fruit



Dried kokum rind

In states like Maharashtra, Goa, Karnataka, and Kerala, kokum holds not only ecological significance but also cultural and economic value. For many tribal and farming communities, kokum is a seasonal source of nutrition and income. Despite its abundance in the Western Ghats, kokum remains underutilized at the national and global levels. However, its increasing recognition as a functional food may change that, offering a sustainable, locally grown alternative to imported health supplements and flavouring agents.

Nutritional and Phytochemical Composition

Kokum is a nutritional powerhouse, primarily due to the wealth of bioactive compounds present in its outer rind and seeds. The most notable among these is Hydroxycitric Acid (HCA), which plays a key role in appetite suppression and fat metabolism. This has made kokum a popular natural aid in weight management supplements. Additionally, kokum contains garcinol, a polyisoprenyl benzophenone, known for its anti-inflammatory, antibacterial, and antioxidant properties. The dark purple colour of kokum rind is attributed to anthocyanins, natural pigments that act as potent antioxidants and protect cells from oxidative stress. These compounds contribute to overall health by neutralizing free radicals and reducing the risk of chronic diseases.

Kokum is also rich in vitamin C, B-complex vitamins (Vitamin B6- 0.18 mg/100g), and essential minerals like potassium (46.93 mg/100g), calcium, magnesium, and manganese. It is low in calories, has no cholesterol, and contains dietary fiber (2 g/100g), making it an ideal food for heart health and digestive wellness. Kokum seeds yield kokum butter, a white, odourless fat high in stearic and oleic acids. This butter is valued for its emollient and skin-soothing properties, commonly used in cosmetics and pharmaceutical formulations. Together, these nutritional and phytochemical components make kokum a promising candidate for use in functional food products aimed at enhancing health and preventing disease.

Health Benefits: Traditional and Scientific Insights

Kokum has been a staple in Ayurvedic and folk medicine for centuries, widely used for its cooling, digestive, and healing properties. Traditionally, kokum juice is consumed to relieve heatstroke, acidity, and indigestion, common ailments in the hot, humid regions of western India. The fruit is known to balance "pitta" in Ayurveda, helping to reduce internal body heat. Modern science supports many of these traditional uses. Kokum's high antioxidant content, particularly garcinol and anthocyanins, helps combat oxidative stress and inflammation, key contributors to chronic diseases like cancer, diabetes, and cardiovascular issues. Research also suggests that garcinol has antibacterial and anti-cancer potential, although further clinical studies are needed.

One of the most explored compounds in kokum is Hydroxycitric Acid (HCA), which has shown promise in weight management by inhibiting fat synthesis and curbing appetite. Kokum is also believed to help in reducing LDL cholesterol and improving digestive enzyme activity. Externally, kokum butter, derived from its seeds, is used to treat cracked heels, dry skin, and rashes. Its non-comedogenic nature makes it suitable for sensitive and acne-prone skin. Thus, whether consumed as a fruit or applied topically, kokum delivers a range of health benefits that make it a valuable part of both traditional and modern wellness systems.

Culinary Uses and Everyday Applications

Kokum, celebrated for its tartness and vibrant red colour, is a versatile ingredient primarily used as sun-dried rinds. It serves as a popular souring agent in Maharashtrian, Konkani, and Goan cooking, often replacing tamarind or tomatoes in seafood curries, lentil preparations, and vegetable dishes. Sol kadhi, a refreshing digestive drink made with kokum extract and coconut milk, is a traditional favourite. Kokum is also the base for kokum sherbet, a cooling summer drink enhanced with cumin, black salt, and sugar. Contemporary cuisine sees kokum in mocktails, sorbets, and salad dressings. Furthermore, kokum tea, pickles, jams, and chutneys are gaining traction. Its butter form finds use in cosmetics. This multifunctional ingredient seamlessly blends traditional uses with modern culinary and personal care applications.

Kokum as a Functional Food: Scientific Validation

Functional foods are defined as those that provide health benefits beyond basic nutrition, often helping in disease prevention or health promotion. Kokum fits this category perfectly due to its unique composition of bioactive compounds. Scientific research is increasingly confirming what traditional knowledge has long upheld that kokum is not just a fruit, but a functional ingredient with medicinal value.

The presence of Hydroxycitric Acid (HCA) in kokum is one of the key reasons for its functional food status. HCA is linked to the inhibition of ATP citrate lyase, an enzyme involved in fat synthesis. This has positioned kokum as a natural alternative in weight management solutions. Moreover, garcinol, a polyphenol found in kokum rind, has shown promising anti-inflammatory, antioxidant, and anti-carcinogenic properties in laboratory studies. Kokum's anthocyanins contribute to its vivid color and act as powerful antioxidants that protect cells against free radical damage. This not only aids in disease prevention but also slows the aging process. Studies also suggest kokum may help regulate blood lipids, manage blood sugar levels, and improve digestive health. With its blend of traditional credibility and emerging scientific support, kokum is increasingly being incorporated into nutraceuticals, functional beverages, and plant-based supplements. It exemplifies how native fruits can be part of a broader wellness narrative, rooted in both local knowledge and scientific validation.

Socioeconomic and Livelihood Aspects

Kokum significantly impacts the socioeconomic lives of rural and tribal communities in the Western Ghats, serving as a seasonal source of nutrition and income through harvesting, processing, and selling. Traditionally a forest product, it's now cultivated in gardens and agroforestry. Women's self-help groups and cooperatives are crucial in managing the value chain, including drying, preservation, and marketing kokum products, ensuring local profit. Despite its economic potential, national commercialization is limited by awareness, price inconsistencies, and infrastructure. However, rising demand for natural and sustainable foods presents new opportunities in urban and export markets. Integrating kokum into health foods and cosmetics supply chains can generate sustainable income with support like training and fair trade, potentially transforming it into a year-round economic driver.

Sustainability, Conservation, and Climate Resilience

Beyond nutrition and medicine, kokum is ecologically sustainable, thriving in the Western Ghats naturally without chemicals or intensive water use. Its compatibility with agroforestry and mixed-crop systems aids biodiversity and prevents soil erosion, making it ideal for climate-resilient agriculture due to its drought and disease resistance. Promoting kokum supports a shift to sustainable farming. However, wild populations face threats from deforestation and overharvesting, risking genetic diversity. Conservation through seed banks, orchard plantations, and genotype documentation is crucial. Sustainable harvesting, cultivation training, and eco-certification can balance conservation with commercial use. Encouraging local cultivation over wild collection reduces habitat pressure, positioning kokum as a flagship for eco-friendly development.

Future Prospects and Innovations

The future of kokum lies at the crossroads of health, innovation, and sustainability. With rising consumer interest in plant-based wellness and natural remedies, kokum is well-positioned to emerge as a globally recognized superfruit. The challenge—and opportunity—lies in expanding its reach beyond traditional markets through innovation and awareness. In the food and beverage industry, kokum is already being incorporated into functional drinks, herbal teas, snack bars, syrups, and fermented beverages. New product lines blending kokum with probiotics, adaptogens, and other superfoods are under development. Chefs and food technologists are exploring kokum's potential in culinary fusion, vegan recipes, and health-focused gourmet cuisine. In the beauty and personal care sector, kokum butter is finding favour as a natural, non-comedogenic alternative to cocoa butter. Its use in organic cosmetics, lip balms, and lotions is growing rapidly, especially among brands focused on clean, green formulations. On the research front, more clinical studies and bioavailability trials are needed to solidify kokum's standing as a scientifically validated functional food. Investments in processing technology, shelf-life enhancement, and branding can take kokum-based products to premium domestic and export markets. By blending tradition with technology, kokum can evolve from a seasonal forest fruit to a mainstream functional ingredient with year-round relevance.

Conclusion

Kokum is a shining example of a functional food that bridges culture, ecology, and health. Rooted in the biodiversity of the Western Ghats, it offers a unique blend of taste, nutrition, and healing properties. Traditionally revered for its cooling and digestive benefits, kokum is now gaining scientific recognition for its antioxidant, anti-inflammatory, and weight-regulating potential. As

consumer awareness grows around plant-based nutrition and sustainable living, kokum presents itself as a valuable, indigenous alternative to imported superfoods. Its cultivation supports climate resilience, its harvesting provides livelihoods, and its use in food, wellness, and cosmetic products has global market potential. To realize Kokum's full promise, there is a need for greater awareness, improved infrastructure, and policy support. By empowering local communities, protecting biodiversity, and investing in research and innovation, Kokum can move from the fringes of food culture to the center of the global health and wellness movement. In embracing kokum, we not only enrich our diets but also reconnect with the wisdom of the land and contribute to a more sustainable and inclusive future.

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KRISHI VIGYAN KENDRA'S (KVKs): THE BACKBONE OF AGRICULTURAL EXTENSION SYSTEM IN INDIA

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Abstract

Krishi Vigyan Kendra's (KVKs) are grassroots-level agricultural institutions established by the Indian Council of Agricultural Research (ICAR) to bridge the gap between the research and farming practices. Originating from the recommendations of the 1964 Education Commission led by Dr. D.S. Kothari, KVKs aim to empower farmers through location-specific trials, skill-based training, and frontline demonstrations. Their mandates focus on sustainable farming practices through "learning by doing" and "teaching by doing." Over time, KVKs have expanded significantly across India's districts, evolving into knowledge hubs supporting innovations like Soil Health Cards and mobile advisory services. In the digital age, KVKs are leveraging ICT tools to ensure uninterrupted knowledge dissemination, especially during crises like COVID-19, thus playing a vital role in shaping the future of Indian agriculture.

Introduction

The roots of establishment of farm science centre popularly known as Krishi Vigyan Kendra's (KVKs) can be found in the recommendations of third education commission in post-independence period. In 1964, an education commission was appointed led by UGC chairman Dr. D. S. Kothari to study the education system in rural area in particular India's agriculture has evolved from traditional subsistence farming to a dynamic system influenced by scientific research, market needs, and environmental changes. Yet, at the heart of this transformation lies an unsung hero-the Krishi Vigyan Kendra (KVK). These grassroots institutions, spread across the country, are silently shaping the future of Indian agriculture by acting as a bridge between scientific innovation and the farmer's field.

Mandates of Krishi Vigyan Kendra:

- 1) To conduct On-Farm Trials (OFT) of agricultural technologies in order to find out the location specific suitability of that technology for sustainable land use.
- 2) To organise training sessions to the farmers and extension personnel to update and enrich their knowledge about modern agricultural research.
- 3) To conduct short term and long-term training programs to the farmers and involving rural youths in agricultural and allied activities on the concept of "learning by doing".
- 4) To organise Front Line Demonstrations (FLDs) of advanced and proven agricultural technologies on various crops to get farmers feedback based on the concept of "teaching by doing".

KVKs conduct On-Farm Testing (OFTs) of different agricultural technologies which are released by various research centres so as to find the applicability and suitability of that technologies for the particular Agro-ecosystem.

Through OFTs the necessary modification in agricultural technologies is carried so as to make them appropriate for adoption. Once the location specificity of the technology is proven through On-Farm Testing, KVKs demonstrate such advanced agricultural technologies by Front Line Demonstrations (FLDs) to the farmers, State extension workers and NGOs can help decrease the duration of time between technology production and implementation. Implementing methods of “Teaching by doing” and “Learning by doing” KVKs provide training to the practicing farmers, rural youth and field level extension functionaries. In recent years, to sustain agriculture and to obtain quality oriented higher production, the Ministry of Agriculture and Farmers’ Welfare, Government of India has emphasized the need of soil testing through “Soil Health Card” scheme nationwide (PIB, 2020). KVKs and they also act as ‘Knowledge and Resource centre’ with the allied activities like Kisan Mobile Advisory Service (KMAS), Laboratory Service, Farm literature and multimedia content development, Production of quality technological inputs and other value-added products for farmer’s benefit.

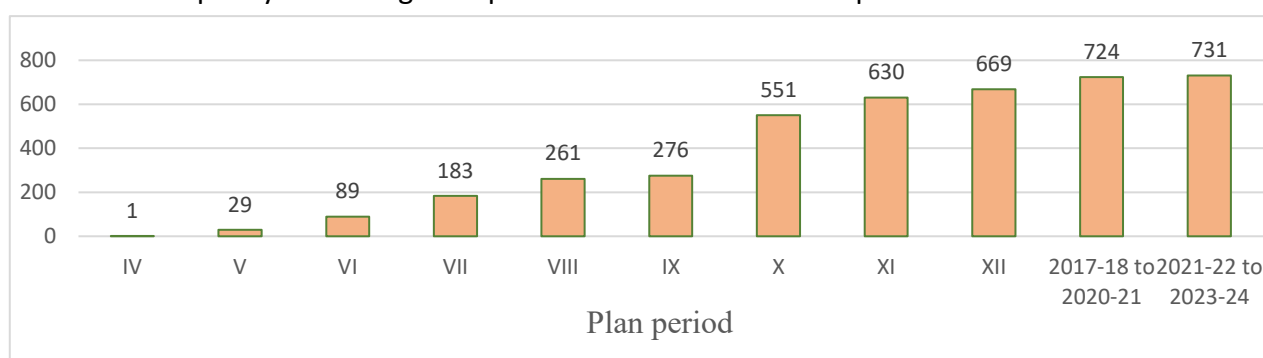


Fig.1: Cumulative Growth in Number of KVKs During Different Plan Periods in India

Source: - ICAR website (www.icar.gov.in)

The bar chart shows the number of Krishi Vigyan Kendra’s (KVKs) during each Five-Year Plan period. Only 1 KVK was set up during the fourth five-year plan, followed by 29 in the fifth Plan and 89 in the sixth Plan. Growth accelerated during the seventh plan (183) and eighth plan (261), continuing modestly in the Ninth Plan (276). A major rise occurred in the tenth Plan (551), with further increases in the eleventh (630) and twelfth (669) Plans.

From 2017–18 to 2020–21, 724 KVKs existed, which rose to 731 by 2023–24. This reflects a steady and strategic expansion of KVKs over time to strengthen agricultural extension.

What are Krishi Vigyan Kendra’s?

Krishi Vigyan Kendra’s, or KVKs, are district-level farm science centres established by the ICAR. The concept was introduced in 1974, with the first KVK set up in Puducherry. Today, over 731 KVKs operate in nearly every district of India, functioning under State Agricultural Universities (SAUs), ICAR institutes, NGOs and other public organizations.

Their core mission is simple yet profound: to transfer agricultural technologies to farmers in a practical, field-level, and farmer-friendly manner.

KVKs in the Digital Era

In recent years, many KVKs have embraced ICT tools to reach farmers. Online webinars, YouTube tutorials, WhatsApp advisory groups, and SMS alerts have expanded their outreach. During the COVID-19 pandemic, when field visits were restricted, these digital initiatives ensured that knowledge flow didn’t stop.

Conclusion

KVKs continue to be the unsung champions of Indian agriculture by empowering farmers with timely, localized knowledge and skills. As they blend traditional outreach with modern digital tools, their role becomes ever more crucial in ensuring sustainable growth. Their silent yet impactful presence is nurturing a self-reliant, progressive, and resilient agricultural ecosystem across India.

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BRIDGING INNOVATION AND AGRICULTURE : ATAL INNOVATION MISSION

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Abstract

The Atal Innovation Mission (AIM), NITI Aayog, and the Ministry of Agriculture & Farmers Welfare (MoA&FW) have collaboratively launched an innovative initiative to connect Atal Tinkering Labs (ATLs) with Krishi Vigyan Kendras (KVKs) and Agricultural Technology Management Agencies (ATMAs). This strategic partnership, inspired by Hon'ble Prime Minister Narendra Modi, seeks to integrate innovation-based learning with real-world agricultural applications, fostering scientific temperament and agri-based problem-solving skills among school students. This article explores the framework, implementation strategy, and early outcomes of the collaboration while reflecting on its potential to create a robust agri-innovation ecosystem in India.

Introduction

India's agricultural sector stands at a critical juncture, demanding technological interventions and innovative approaches to tackle persistent challenges such as climate change, declining productivity, and post-harvest losses. At the same time, nurturing young minds to become innovators and problem solvers has become a national priority. Recognizing the potential of synergizing these two domains, the Atal Innovation Mission (AIM), under NITI Aayog, and the Ministry of Agriculture & Farmers Welfare (MoA&FW) have initiated a path-breaking collaboration. This initiative connects Atal Tinkering Labs (ATLs)—dedicated spaces for innovation in schools—with Krishi Vigyan Kendras (KVKs) and Agricultural Technology Management Agencies (ATMAs), the grassroots institutions of agricultural knowledge and extension (Atal Innovation Mission, 2025).

The overarching goal is to inculcate a spirit of innovation among students while addressing real-world agricultural problems, thereby creating a generation of agri-innovators who are both technologically adept and socially responsive.

Connecting Schools with Agriculture Innovation Ecosystems

Atal Tinkering Labs are creative innovation hubs established in over 10,000 schools across India to foster curiosity, creativity, and critical thinking among students from Classes 6 to 12. Equipped with modern tools like 3D printers, IoT kits, and robotics platforms, ATLs encourage experimentation and solution-building in a hands-on manner (Tripathi, 2024).

On the other hand, Krishi Vigyan Kendras (KVKs) function as "Single Window Agricultural Knowledge Resource and Capacity Development Centres," delivering localized agricultural technologies and training to farmers. By linking ATLs with KVKs and ATMAs, this initiative bridges the gap between formal education and grassroots agricultural practices.

Pilot Implementation and Strategic Mapping

The collaboration commenced with a pilot phase involving one KVK under each of the 11 Agricultural Technology Application Research Institutes (ATARIs). AIM mapped and connected these KVKs and

ATMAs to 55 selected ATL schools, ensuring regional balance and diversity. KVK experts are tasked with conducting need-based visits to ATL schools to provide:

- Technical guidance and mentoring
- Seeds and planting material
- Agricultural literature and manuals
- Practical inputs for agri-based experiments

This strategic mapping aims to generate a two-way knowledge exchange—students gain exposure to practical agricultural practices while KVKs benefit from the fresh perspectives of youth innovators.

Quarterly Showcases and Hackathons

To encourage innovation and recognize outstanding student efforts, AIM and MoA&FW plan to organize **quarterly showcases** at the Ministry, where young Agri-student innovators will be felicitated. Furthermore, the institutions are exploring the development of a “**problem-finding platform**” and hosting **agri-hackathons**, enabling students to work on real-world problems in collaboration with experts and peers (Phatak & Mane, 2022).

Scaling the Innovation Ecosystem

This initiative complements AIM's larger portfolio of national programs:

- **Atal Incubation Centres (AICs)**: 72 centres supporting over 3,500 startups, generating 32,000+ jobs.
- **Atal Community Innovation Centres (ACICs)**: Extending innovation ecosystems to underserved regions with Rs. 2.5 crore grants on a co-funding model.
- **Atal New India Challenges (ANIC)**: Supporting deep-tech startups in sectors like AgriTech, FinTech, HealthTech, and Food Processing with up to INR 1 crore in funding.
- **Mentor India Network**: A robust pool of over 6,200 registered mentors guiding students, startups, and innovators across the country.

Special initiatives

Atal Krishi Mitra : This initiative focuses on increasing agricultural productivity and reducing farmers' costs through innovative solutions developed by students in ATLs.

Waste Water Treatment : AIM also supports innovations in decentralized wastewater treatment for industries, including those in the agriculture sector, to address water pollution and promote sustainability.

Conclusion

This pioneering collaboration between AIM and MoA&FW signals a powerful shift toward innovation-led, integrated education and agricultural development. By linking students directly with agricultural challenges and knowledge systems, the initiative fosters a new generation of thinkers and doers equipped to lead India's agri-transformation. The fusion of young energy with field expertise promises not only to enhance agricultural productivity and sustainability but also to reposition agriculture as an aspirational career path for India's youth.

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FROM ROOFTOPS TO ROOT DROPS ; REVOLUTIONIZING URBAN GARDENING

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Abstract

Rooftops to root drops takes a closer look at how drip irrigation is changing the way we grow food in cities. With more people living in apartments and limited ground space, terrace gardening has become a smart and sustainable option. This piece shows how using drip irrigation—where water slowly reaches the roots of each plant—makes rooftop gardens more efficient, saving water and effort while giving better results. It's about making gardening easier for city folks, turning unused terraces into green, productive spaces that bring nature back into our everyday lives.

Keywords : Drip Irrigation, Terrace Farming, Fertigation, Urban gardening

Introduction

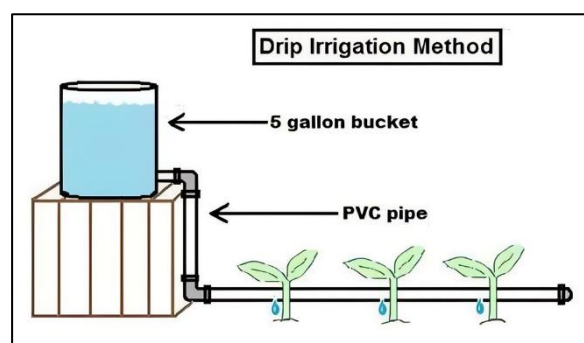
In today's world, where space is limited and the need for fresh, chemical-free, home grown vegetables are getting prioritized, rooftop farming/terrace farming has become a popular choice for many urban households. Turning rooftops into small farms not only helps in utilizing unused space but also brings us closer to nature. However, managing water effectively in terrace farming can be a challenge, especially in cities where water availability is limited. This is where drip irrigation comes in.

Drip irrigation is a smart watering method that slowly supplies water directly to the roots of plants through a network of tubes and emitters. It ensures that plants get just the right amount of water, reducing wastage and improving plant health. It's especially useful for terrace farms, where water needs to be carefully managed to avoid over-watering and leakage issues. Using drip irrigation in terrace farming not only saves water but also saves time and effort. It allows busy individuals to maintain their rooftop gardens with ease and helps in growing a variety of vegetables and fruits efficiently. With the right setup, even a small terrace can turn into a highly productive green space. This method supports sustainable living and offers a healthy, eco-friendly solution for growing food in urban settings.

Anatomy of drip irrigation in terrace farming

Drip irrigation is a smart and efficient way to water plants, especially in limited spaces like terrace gardens. Here's a breakdown of how the system works and the key parts involved:

1. Water Source : Every drip irrigation system begins with a water source. This could be a storage tank, water barrel, or even a tap. In terrace farming, a tank is often placed at a height to allow gravity-based flow, or a small motor pump is used for better pressure.



2. Filter Unit : The filter helps remove dust, sand, and other particles from the water before it flows through the pipes. This is important because small holes in drip emitters can easily get blocked without filtration.

3. Main Supply Pipe : A larger pipe (usually PVC or HDPE) carries the filtered water from the source to different parts of the terrace. It acts like the backbone of the system.

4. Sub-Main Pipes : These are smaller pipes that branch out from the main pipe to reach various grow bags, pots, or beds on the terrace. They help distribute water evenly to all areas.

5. Drip Laterals / Tubes : These are thin, flexible pipes laid along the base of the plants. They contain small openings or emitters that release water slowly and directly at the root zone.

6. Drippers / Emitters : Drippers are fixed into the laterals and control the flow of water. They ensure that each plant gets just the right amount of water, drop by drop, reducing waste.

7. Control Valves : Valves help to regulate or stop the water flow to different sections. Some systems include a timer to automate watering at specific times of day, which is very convenient.

8. End Cap or Flush Valve : These are placed at the end of each pipe to close the system and allow cleaning. Regular flushing helps remove any dirt and keeps the system running smoothly.



Filter Unit



Main supply pipe



Drippers/Emitters



Control Valve



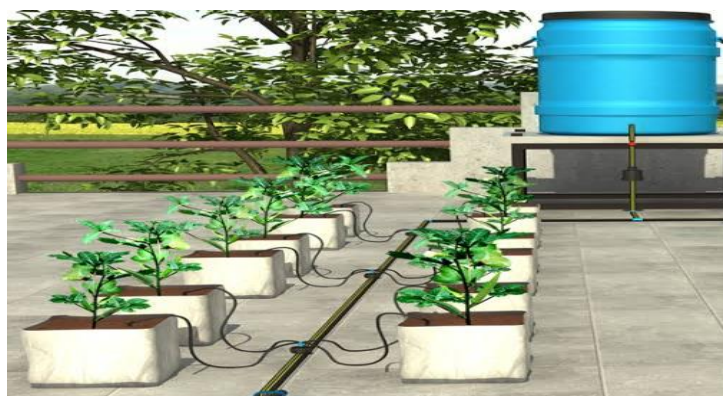
Sub main pipe



Drip laterals



End cap/Flush Valve



Final Setup of Drip Irrigation in Terrace Farming

Setting up of Drip Irrigation system in Terrace

The process begins with understanding the layout of the terrace and the arrangement of plants—whether in pots, grow bags, or raised beds. The entire setup revolves around a central water source, typically a water tank that can either be gravity-fed or connected to a small pump. This tank supplies water to a network of pipes that are carefully laid out across the terrace.

Mainline pipes run from the tank and branch out into smaller lateral pipes, which reach each individual plant. At each plant, a dripper or emitter is fixed near the base to deliver water directly to the root zone. These emitters release water slowly and consistently, drop by drop, making sure the plant receives just the right amount of moisture without any wastage. The number of emitters and their flow rate can be adjusted based on the water requirement of different plants. Before water enters the system, it is passed through a filter to prevent dust and debris from clogging the emitters. Once installed, the system is tested to ensure all drippers are functioning properly and water is reaching every plant. Regular maintenance, such as cleaning filters and occasionally flushing the pipes, keeps the system running smoothly. Drip irrigation in terrace farming reduces the effort of daily manual watering, saves water, and enhances plant health by preventing overwatering. It is an ideal solution for urban gardeners looking to manage their terrace gardens more efficiently while conserving natural resources.

Fertigation

Fertigation in terrace farming through a drip irrigation system is a smart and efficient way to nourish plants while saving time, water, and effort. By mixing water-soluble fertilizers directly into the drip lines, nutrients reach the plant roots gradually and precisely.

Schemes for establishing Drip Irrigation in Larger Area

- Pradhan Mantri Krishi Sinchai Yojana (PMKSY)
- PM-KUSUM Scheme

Merits and Demerits of Drip Irrigation

Aspect	Merits (Advantages)	Demerits (Disadvantages)
Water Efficiency	Delivers water directly to plant roots, which is vital in small terrace gardens.	Any leakage can lead to water damage to the building or stains on walls/floor.
Space Management	Compact and customizable can be set up around pots, grow bags, or raised beds easily.	Improper layout can make the terrace look cluttered or untidy.
Plant Health	Prevents fungal diseases by keeping foliage dry; promotes healthier growth.	If not maintained, clogged emitters can affect plant health or lead to under-watering.
Time & Effort	Automates watering - ideal for busy urban gardeners or working individuals.	Needs regular checks, especially in dusty or polluted city environments.
Weight Load	Lightweight tubing reduces additional load on terrace structures.	Overuse of water or leaks may increase structural stress if drainage is poor.
Water Conservation	Minimizes water usage - helpful in cities facing water shortages.	Requires filtered water; tap water with impurities may cause blockages.
Ease of Use	Once set up, very easy to use with timers or gravity-fed tanks.	Initial setup may be tricky for beginners without guidance or support.
Cost Factor	Long-term cost-effective as it reduces water bills and plant loss.	Initial investment (pipes, timers, filter) can be high for small terrace farmers.
Aesthetics	Neat piping can enhance the modern garden look.	Poorly installed systems can make the terrace look messy or unappealing.

Conclusion

Drip irrigation in terrace farming offers a smart, sustainable solution for urban agriculture by efficiently using limited space and water. It delivers water and nutrients directly to plant roots, reducing wastage, boosting yields, and minimizing labor through automation. While it requires some initial investment and maintenance, the long-term benefits like higher productivity and environmental sustainability make it a valuable choice for city dwellers. With growing awareness and government support, this method is transforming rooftops into vibrant, eco-friendly gardens.

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IFFCO'S NEW AGE SMART FERTILIZERS FOR SUSTAINABLE HIGH-QUALITY YIELD OF RAINY SEASON CROPS AND ENVIRONMENTAL SECURITY

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To feed the growing population, the demand for food grains as well as vegetables and fruits is increasing, but the poor efficiency of traditional fertilizers is hampering crop production. As we see, agricultural productivity is decreasing day by day, because the agriculture sector is facing many problems like increasing ill effects of climate change, depletion of natural resources (land, water and biodiversity) in quest to ensure food and nutrition security through intensive agriculture which is already facing the problems of decreasing efficiency of fertilizers and spread of multi-nutrient deficiency due to unbalanced and inefficient use of fertilizers coupled with increasing problems of pests (insect, diseases and weeds) due to mono cropping system. Since it is no longer possible to expand cultivable land, effective nutrient and water management to increase nutrient and water use efficiency and pest management can be an ideal way to achieve sustainable high crop production. For decades, chemical fertilizers and pesticides are being used to increase agricultural productivity but this is not only reducing the yield and quality of the product but it is also affecting the soil, human and animal health, and the environment. Therefore, a new agricultural revolution is urgently needed to ensure adequate availability of quality food for the rapidly growing population of the world. To overcome these problems, the development of nanoscience based fertilizer technology is being seen as a solid possibility of miraculous changes in the agricultural sector.

IFFCO Nanofertilizers are playing an important role in arresting increasing demand of fertilizers as well as help increasing agricultural production through improved nutrient use efficiency. These smart fertilizers have shown significant impact on various aspects of agriculture, including improved seed germination, improved growth and development of plants due to better crop nutrition through increased nutrient use efficiency resulting increased crop productivity. Besides these benefits, Nanofertilizers mitigate ill effect of biotic and abiotic stresses as a result of development of resistance in crop plant to abiotic and biotic stresses. The ultra-fine particles (typically 1-100 nanometers) and high surface area of nanofertilizers play an important role in increasing the productivity of crops with high nutrient use efficiency and minimum cost as a result of its easy penetration into the plant systems ensuring slow release of nutrients to the targeted site. This paper aims at highlighting the growing importance of IFFCO's nano fertilizers, specialty fertilizers and bio stimulants (Plant growth promoters) like Sagarika and their right rate, right time and right method of application towards increasing the yield, quality of produce, farmer's profits and future perspectives.

The growing Importance of Nanofertilizers

Fertilizers based on nanotechnology have the potential to surpass conventional fertilizers. Mineral nutrients if applied to crops in the form of NFs hold potential to offer numerous benefits for making the crop production eco-friendly and more sustainable. The benefits of NFs are summarized below:

1. **Importance superiority over conventional fertilizers due to comparatively higher solubility and**

diffusion.

2. Increase the bioavailability of nutrients due to miniature size, high specific surface area and high reactivity.
3. Influence metabolic activities of the plant to different degrees and have the potential to mobilize native nutrients in the rhizosphere due to their unique properties.
4. Provide plant nutrients gradually in a controlled manner in contradiction to rapid and spontaneous release of nutrients from chemical fertilizers.
5. Ensure higher efficiency of nutrient uptake matching the uptake pattern of the crop in a controlled manner by slow, and targeted efficient release. For example, nutrients can be released over 30 days in a slow-release fashion. Research has shown that NFs release nutrients as much as 12 times slower than fertilizers, and they can significantly increase the yields and quality traits of crops.
6. Prevent undesirable nutrient losses to soil, water and air via direct internalization by crops, and avoiding the interaction of nutrients with soil, microorganisms, water, and air that enhance the NUE and reduce the costs for environmental protection.
7. Avoid premature contact with soil and water due to thin coating encapsulation of nanoparticles such as leading to negligible loss of nutrients. These become available as soon as plants are in position to internalize the released nutrients.
8. More efficient in terms of nutrients absorption and utilization due to considerably lesser losses through leaching and volatilization and offer lower risk of environmental pollution.
9. Ensure significantly higher uptake owing to free passage from nano sized pores and by molecular transporters as well as root exudates. Nanoparticles also utilize various ion channels which lead to higher nutrient uptake by crop plants. Within the plant, nanoparticles may pass through plasmodesmata that results in effective delivery on nutrient to sink sites.
10. Applied in smaller amounts due to considerably small losses of nano fertilizers in contrast to synthetic fertilizers which are being applied in greater quantities keeping in view their major chunk that gets lost owing to volatilization, leaching, eutrophication, emission etc. resulting poor use efficiency.
11. Prevent undesirable nutrient losses to soil, water and air via direct internalization by crops, and avoiding the interaction of nutrients with soil, microorganisms, water, and air that enhance the NUE and reduce the costs for environmental protection.
12. Facilitate the crop plants to fight various biotic and abiotic stresses by providing balanced nutrition.
13. Minimize over accumulation of salt in soil as they are required in small amount.
14. Useful for mitigating the chronic problem of moisture retention in arid soils and enhance crop production by increasing the availability of nutrients in the rhizosphere.
15. Required in small amount thus reduce the cost of transportation and field application.

The world's largest cooperative (Indian Farmers Fertilizer Cooperative Limited- IFFCO) took lead to invent Nanofertilizers viz. Nano nitrogen, Nano Zinc and Nano Copper in liquid form and initiated large scale on-station and on-farm testing since 2019.

Nutrient Management in Rainy Season Crops

Kharif crops include cereals (Rice, maize, pearl millet, sorghum and smaller millets), pulses (pigeonpea, uradbean, mungbean, cowpea, cluster bean) and oilseeds (peanut, sesame, soybean)

as well as many vegetable crops are cultivated. Proper nutrition of crops through optimal nutrient management is a big challenge across the world, as it is mainly based on chemical fertilizers. Traditional fertilizers are not only expensive for the producer and growers, but also prove harmful to soil, water, humans, animals and the environment. Therefore, there is a need to minimize the use of chemical fertilizers like urea, DAP etc, as much as possible in the coming years. On 15 August 2019, Prime Minister Modi appealed to the farmers of the country that to maintain the health of our mother earth, it is necessary that we reduce the use of chemical fertilizers. Nano fertilizers developed by IFFCO using nanotechnology have provided a way to address the issues of food, nutrition and environment security, and quality constraints in agriculture in a systematic way. The use of controlled release fertilizers reduces nutrient losses due to volatilization and leaching and provides slow nutrient release in consonance with the objective of sustainable agriculture. Nanofertilizers are more effective than normal chemical fertilizers due to their slow nutrient release properties and are helpful in controlling various environmental problems of agriculture (increasing abiotic (temperature, humidity, rainfall, drought, frost, soil alkalinity, salinity etc.) and biotic stresses (insects, diseases) due to climate change caused by the growing problem of global warming. Recently, IFFCO has developed nanotechnology based fertilizers like Nano Urea Plus, Nano DAP and Nano Zinc and nano copper. These nano fertilizers have proved to be effective in ensuring balanced crop nutrition by slow and controlled release of nutrients. The nutrient use efficiency of nano fertilizers is also far better than the common fertilizers. Nano particles improve soil health by promoting soil microbiota, which is responsible for healthy plant growth and development. Engineered nano particles have opened up an entirely new direction towards overcoming uncertainties of agricultural constraints, that too with minimum cost. The revolution brought about by the introduction of nanomaterials in the form of nanofertilizers has shown incredible results in meeting global food demands and ensuring sustainable agriculture. Nanofertilizers are effective in maintaining soil pH, adequate levels of organic matter, and other essential processes.

Nano Urea Plus

The Union Government had notified IFFCO Nano Urea Plus for three years in the Fertilizer Control order. This is an advanced formulation of IFFCO's Nano Urea, In which the nutrition has been redefined and formulated to meet the nitrogen requirements of the crop. It is used as a supplement to conventional urea and other nitrogenous fertilizers. It reduces the amount of granular urea and DAP by 30-50%. The amount of nitrogen in IFFCO Nano Urea Plus has been increased to 20 percent. Due to its special efficiency, it can significantly increase the nitrogen use efficiency of crops and increase the crop yield by 5-6 %. As the Nanofertilizers help increasing the availability of other nutrients also, which in turn promote balanced crop nutrition. The main objective of Nano Urea Plus being made available by IFFCO without subsidy is to benefit the farmers through efficient use of this smart fertilizer and to ensure the protection of the environment in a sustainable manner. It promotes the availability of other nutrients besides nitrogen. It works as a nitrogen supplement and chlorophyll charger. Nanofertilizers mitigate the ill effect of climate change. This will prove to be helpful in view of the increasing problem of diseases and insects. Despite the higher amount of nitrogen, IFFCO has not increased the price of Nano Urea Plus. Like before, it will also be available at the rate of Rs 225 per kg for Rs 500. It is available in 100 ml bottles. With the continuous efforts of the government and IFFCO, farmers across the country have now accepted Nano Urea. Nano Urea Plus will provide special assistance in the growth and development of plants and crop yield with less amount of urea without harming the environment and increased farmers profit. Nano Urea Plus is

now going to be a big step towards prosperity through cooperation, paving the way for self-reliant agriculture in India.

IFFCO Nano Urea Plus offers several benefits including increased crop yields, higher quality food, reduced chemical fertilizer usage, and environmental friendliness. It's also easier to store and transport, and it can lead to increased income for farmers. Given below is a more detailed look at the benefits:

- **Higher Crop Yields:** Nano Urea Plus enhances nutrient availability to crops, leading to better yields.
- **Better Food Quality:** It improves the overall quality of food produced.
- **Reduced Chemical Fertilizer Usage:** Nano Urea Plus can significantly reduce the amount of traditional urea needed, potentially by as much as 50%.
- **Environmentally Friendly:** It minimizes nutrient losses from agricultural fields through leaching and gaseous emissions, reducing pollution and the impact of climate change.
- **Easy to Store and Transport:** Its liquid form makes it easier to store and transport compared to granular urea.
- **Increased Income for Farmers:** By increasing yields and potentially lowering input costs, Nano Urea Plus can contribute to higher farmer incomes.
- **Supports Sustainable Agriculture:** Nano Urea Plus is a key component in promoting precision farming and sustainable agricultural practices.
- **Efficient Nutrient Use:** Nano Urea's smaller particle size and larger surface area allow for better absorption and utilization by plants, increasing nutrient use efficiency.

Mode of Action of IFFCO Nano Urea Plus

Foliar sprays of IFFCO Nano Urea Plus (liquid) with half the amount of urea at the critical growth stages of the crop successfully fulfills the nitrogen requirement of crops. After foliar spraying, the micro particles of nano urea easily enter the leaves through the stomata and are absorbed by the plant cells. These particles are easily distributed to other parts of the plant as per the requirement through phloem. After the plant uses nitrogen as per need of the plants, the remaining nitrogen gets stored in the vacuoles and is released slowly as per the requirement and contributes to the growth and development of the plant. Obviously, its use not only saves conventional urea but it is also cheaper than urea and the problem of environmental pollution also minimized. The scientists involved in testing IFFCO nano urea reported that it reduces the use of urea by 30 to 50%. The fertilizer use efficiency of nano urea is much better than conventional urea. The nano urea particle is 55000 times smaller than a particle of ordinary urea. While its surface area is 10,000 times more than a particle of conventional urea this provides nutrients to the plants as per their requirement and provides better nutrition. In the very first year, farmers of the country adopted nano urea on a large scale along with conventional urea. Due to this, farmers benefited from nano urea which is more efficient than conventional urea.

Nano DAP (Liquid) :

With the successful effort of IFFCO, India became the first country in the world to commercially produce Nano DAP in 2023. IFFCO has 8 March, Started production of Nano DAP at its Kalol plant from 2023. Two more plants, It will be started in Kandla and Paradip. It is noteworthy that compared to traditional DAP, the use of liquid nano DAP reduces the number of roots, shoots, etc. of plants . number of earrings, A significant increase has been observed in the weight of the ears and grains

and in the crop yield. The encouraging results of Nano DAP (liquid) are confirming the fact that this liquid nano fertilizer is more efficient and effective than the traditional DAP. In such a situation, the Ministry of Fertilizers and Chemicals of the Government of India is of the opinion that after the introduction of Nano DAP in the market, the Central Government will not only save lakhs of crores of rupees in subsidy, but also, as Nano DAP fertilizer will be available to farmers at less than half the price of DAP, it is proving to be a very useful and successful product for the farmers. These nano fertilizers (Nano Urea and Nano DAP) will not only prove important for achieving the highest economic yield of crops due to better fertilizer capacity, Rather, the environment will also be protected by their judicious use. Nano fertilizers will create immense employment opportunities for the youth in this field.

Benefits of IFFCO Nano Urea Plus and Nano DAP at a glance are shown in Picture 1.



Picture 1. Benefits of IFFCO Nano Urea Plus and Nano DAP

Be it Nano Urea Plus, Nano DAP, Nano Zn or Nano Cu, all these are the successful outcome of IFFCO in commensuration with the call given by Prime Minister Shri Narendra Modi to promote the use of Nanofertilizers, water soluble fertilizers and bioenhancers to reduce the use of chemical fertilizers.

Method of application of Nano DAP

The use of Nano DAP starts with the treatment of seeds and roots of the plant before sowing or transplanting. This helps in quick germination of seeds, development of roots and establishment of plants after transplanting. After this, it is necessary to spray Nano DAP after 25-30 days in seed sown crops and after 20-25 days in transplanted crops. If one of the two, that is the seed treatment and the foliar spray, if any one is missed, the use and effect of Nano DAP remains incomplete. Hence, to get full benefit from Nano DAP, both seed/ plant root treatment and foliar spraying of Nano DAP in right quantity and at right time are mandatory tasks. Picture 2 shows the method of treating the roots of rice seedlings with Nano DAP followed by transplantation and foliar spray and Picture 3 shows the method of using Nano DAP in maize.



Picture 2. In rice, first of all, prepare a solution of 5 ml of Nano DAP per liter of water and purify the roots of the plant for half an hour. After 20-25 days, mix two and a half caps of Nano DAP in the 15-liter tank of the sprayer and spray the solution on the leaves before noon or after 3 pm. After 15 days, spray Nano Urea Plus at the same rate with half the amount of urea and half its amount of Sagarika liquid.



Picture 3. In maize, first of all, purify the seeds with IFFCO Nano DAP at the rate of 5 ml per kilogram of seed for half an hour. After 20-25 days, mix two and a half caps of Nano DAP in the 15-liter tank of the sprayer and spray the prepared solution on the leaves before noon or after 3 pm. After 15 days, mix IFFCO Nano Urea Plus with half the amount of urea at the same rate and half its amount of Sagarika liquid and spray it on the leaves.

Nano Zinc and Nano Copper:

Nano Zinc and Nano Copper developed by IFFCO have recently been included in the Fertilizer Control Order (Picture 4). Nano Urea Plus, Nano DAP, Nano Zinc and Nano Copper, The results of the tests conducted on all these in the farmers' fields and the research fields of various research institutes of the country have shown that all of these are quite effective. These fertilizers meet the needs of environmentally friendly farming.



Picture 4. IFFCO Nano Zinc and Nano Copper Note: Apply Nano Zinc and Nano Copper both @ one ml. in one liter water or say 15 ml. in one tank of 15-liter capacity of the sprayer in the forenoon or in the afternoon at 3 PM.

Sagarika (granular and liquid):

Along with these, marine plant growth stimulants like IFFCO's Sagarika which are available in granular (for basal use) and liquid form (for foliar spray) whose integrated use with nano fertilizers is proving to be an effective option of crop nutrition for green agriculture (**Picture 5**). Sagarika has now become the choice of farmers, As a result, its demand is constantly increasing. The main benefits of Sagarika are given here.

- Enhances internal growth and development of crops.
- Provides the crop the ability to absorb nutrients properly.
- Increases the yield and product quality.
- size of fruits , Enhances the quality of colour and taste.
- Various types of biotic and abiotic stresses in crops such as diseases, Insects, excess heat, Increases immunity against cold etc.
- Increases the number of microorganisms in the soil and activates them, thereby improving soil health.

Table 1. Composition of Sagarika

TABLE 1. COMPOSITON OF SAGARIKA	
NITROGEN	0.25-30 g/100g
PHOSPHORUS	0.03-0.04 g/100g
POTASSIUM	0.14-0.18 g/100g
SODIUM	1.0-1.5 g/100g
CALCIUM	0.15-0.20 g/100g
SILICA	0.20-0.25 g/100g
MAGNESIUM	0.35-0.45 g/100g
IRON	0.02-0.03 g/100g
SULPHUR	0.10-0.15 g/100g
COPPER	50-70 ppm
MAGANESE	15-20 ppm
COBALT	5-10 ppm
ZINC	5-12 ppm

Picture 5. IFFCO Sagarika granular and liquid for basal application and foliar spray

The quantity of chemical fertilizers can be reduced by using IFFCO Nano fertilizers:

It is important to mention, how the quantity of conventional fertilizers like urea and DAP can be reduced by using so low quantity of Nanofertilizers. It is worth noting that today special effective smart fertilizers like IFFCO Nano Urea Plus and Nano DAP are available at IFFCO's agricultural investment sales centers. It is worth mentioning that nanotechnology is emerging as a promising option. Nano fertilizer is a product made of nanoparticles. These fertilizers have been produced and evaluated as a way to increase nutrient use efficiency and improve plant nutrition compared to conventional fertilizers. Nanotechnology based fertilizers have large surface areas and slow stable release of nutrients at targeted site resulting in increased crop productivity, product quality and economic benefits. The use of nano fertilizers increases the resistance of plants to biotic and abiotic stresses because the absorption of nutrients by crops is higher when nano fertilizers are used, which leads to environmental protection and resistance to biotic stress in the crop. Smart delivery of nutrients using nano fertilizers helps in reducing the dosage of conventional fertilizers and increasing nutrient use efficiency. Nano urea plus helps reducing gaseous nutrient loss and also the loss of nitrate through leaching and denitrification during the life cycle of the crop Nano DAP helps to reduce losses due to runoff and the energy consumed. Thus, Nano fertilizers prove helpful in providing the right amount of nutrients to the crop at the right time, Additionally, the control of nutrient wastage helps dramatically in environmental protection and improvement.

IFFCO Nano Fertilizer Promotion Campaign:

IFFCO launched a Mahabhiyan to create awareness among farmers about the use of nano fertilizers from July 2023. A total of 200 clusters have been formed in different states under this campaign, In which Nano Urea Plus will be available in 2000 acres area in each cluster, Nano DAP and Sagarika are being used through drone sisters (Figure 6). These fertilizers are being made available to all the farmers of these clusters by IFFCO at 25 percent cheaper rate. These cluster villages have been linked to one fertilizer sales center of IFFCO.



Picture. 6 Foliar sprays of nano fertilizers by IFFCO Drone Didi through drone for IFFCO Nano Fertilizer promotion

Joint Application of nano fertilizers and Sagarika

Farmers are convinced of the benefits of integrated use of nano fertilizers and Sagarika. What is required is that they should be used in the right quantity at the right time and in the right way. For

integrated use, whether it is sowing seeds in the nursery or growing the crop by direct sowing of seeds or planting saplings, Treating seeds or seedlings with Nano DAP would be the first step. **5** Mix 1 ml Nano DAP per kg of seed or 5 ml Nano DAP per liter of water and let the seed or plant remain in the solution for half an hour, Then, take it out and reduce the amount of DAP by half and mix 10 kg of Sagarika granular in the furrow, otherwise sprinkle it and do the sowing/planting. After this, spray the DAP on the planted crop after 20 days and on the sown crop after germination after 30 days. on the day Spray Nano DAP on the leaves by adding 4 ml Nano DAP per liter of water i.e. two and a half caps in a 15 liter sprayer tank. After 10 days of this, mix Nano Urea Plus and Sagarika (liquid) and spray on the leaves together. Keep the quantity of Nano Urea Plus the same as mentioned for Nano DAP and keep the quantity of Sagarika half of it. If necessary, add sulphur, bentonite sulphur to overcome zinc and boron deficiency, Zinc sulphate monohydrate and boron (20 per cent. Ensure basal use of 100 % fertilizers. Otherwise, foliar spraying can be done with Nano Urea Plus and Sagarika. For green agriculture, use organic agrochemicals for plant protection. This can help in avoiding the toxic effects of chemical agroprotection chemicals.

Water Soluble Fertilizers:

A number of fully water soluble fertilizers are available to reduce greenhouse gas emissions and increase nutrient use efficiency. Fully water soluble NPs are available for a balanced supply of nutrients. NK, Fertilizers containing NPS and NPK are important (Picture 7). Water soluble fertilizers made from high quality raw materials are intended to ensure the supply of essential nutrients to crops in any situation and stage of crop growth. Let us tell you 20 Market size of water soluble fertilizers in the year 2000 10,000 in the early 1990s tonne to 2021 30,0000 tonnes in 2019. World water soluble fertilizers market size by year 2023 in 18.3 billion US dollars and was projected to reach 2028 in 25.1 It is estimated to reach US\$ billion.



Figure 7. IFFCO Speciality

Joint Application of water soluble fertilizers and biostimulant (Sagarika)

Water soluble fertilizers and plant growth stimulants are essential components of nutrient management for vegetables and fruit trees, Because they help ensure healthy growth of plants, Helps to increase yield and improve fruit quality. Plant growth stimulants from the seaweed-based product range can be used during vegetative stage, It is especially beneficial during flowering and fruit setting. Proper use of plant growth promoters along with water soluble fertilizers can

significantly reduce chemical fertilizer waste accumulation and environmental impact while promoting plant growth and improving fruit quality .

Summary

The smart new age fertilizers of IFFCO (Nano Urea plus, Nano DAP, Nano Zinc and Nano Copper), Plant growth stimulants like Sagarika and water soluble fertilizers are not only important for obtaining maximum economic yield of crops due to their better use efficiency, but their judicious use also protects the environment. The need is that these smart fertilizers should be used in the right quantity, at the right time and in the right way. Nano fertilizers, bio stimulants and water soluble fertilizers will prove to be important in the adverse conditions of climate change. Not only this, when their demand will increase in the future, then their necessary supply at the desired place on time and for the right advice will create immense employment opportunities for the youth in this field.

INFLUENCE OF LAND USE CHANGE AND SOIL TEXTURE ON HYDRAULIC CONDUCTIVITY AND WATER DYNAMICS IN HUMID SUBTROPICAL REGIONS: A REVIEW

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Abstract

Soil hydraulic conductivity (K) is crucial for water infiltration, redistribution, and availability, directly impacting irrigation efficiency, crop productivity, and flood regulation. In humid subtropical India, variations in K, driven by soil texture and land use changes (LUC), significantly influence water dynamics. Agricultural expansion, urbanization, and deforestation degrade soil structure, reduce infiltration, and increase runoff. Field studies and remote sensing reveal that management practices like conservation tillage and organic amendments can mitigate these impacts by improving soil porosity and hydraulic conductivity. Understanding the interactions between LUC, soil texture, and K is essential for sustainable water resource management and climate-resilient agriculture in this region.

Keywords: Soil hydraulic conductivity, Land use change (LUC), water resource management

Introduction

Soil hydraulic conductivity, the ability of soil to transmit water, is vital for water infiltration, redistribution, and availability, directly affecting runoff, groundwater recharge, irrigation, and crop productivity (Hillel, 1998; Šimůnek *et al.*, 2003). It varies with soil texture and external pressures, influencing sustainability and hydrological processes like flooding and erosion (Mohanty *et al.*, 2017). Fine-textured soils have lower conductivity, while coarse soils allow faster water flow (Rawls *et al.*, 1982). In humid subtropical, agriculturally intensive regions, managing soil water is crucial to maintain yields and prevent degradation (Wang *et al.*, 2014). Land use changes, such as deforestation and urbanization, alter soil structure and water dynamics (Fu *et al.*, 2000; Yang & Zhang, 2011). This review focuses on the combined effects of soil texture and land use change on hydraulic conductivity in humid subtropical zones to guide better land and water management.

Soil Hydraulic Conductivity: Concepts and Importance

Saturated vs. Unsaturated Hydraulic Conductivity : Soil hydraulic conductivity (K) measures water flow in saturated and unsaturated soils. Saturated K (K_s) is key for drainage and recharge, while unsaturated K controls plant water uptake and evaporation (Garg *et al.*, 2025; Liu *et al.*, 2025). In India, K_s ranges from 103–124 mm/hr in Punjab's sandy soils to 7–27 mm/hr in the fine-textured Gangetic plains (Kumar *et al.*, 2025).

Mechanisms Influencing Water Movement : Infiltration improves with root growth and tillage but declines under compaction (Kumar *et al.*, 2025). Conservation agriculture enhances K_s by 20–30% (Garg *et al.*, 2025), while wastewater irrigation reduces K by 30–60% due to pore clogging (Zhang *et al.*, 2019). Seasonal factors like monsoon and freeze-thaw cycles also cause K variability.

Role in Water Retention, Drainage, and Plant-Available Water : Loamy soils with moderate K retain more water for plants. Biochar increases micropores, improving moisture retention by 9–13% (Garg *et al.*, 2023). High Ks in Bengal basin soils prevents waterlogging (Kumar *et al.*, 2025). Fluctuating K in the Gangetic plains can reduce plant-available water by up to 44%, highlighting the need for careful irrigation scheduling.

Regional Challenges and Innovations : Over-extraction of groundwater in Punjab and Haryana (137% usage) demands precise K monitoring (CGWB, 2023). Innovations like nano-clay additives can reduce K by 97% in landfill liners where clay is scarce (Guo *et al.*, 2025). Accurate K assessment is essential for water sustainability and climate resilience in India.

Soil Texture and Its Influence on Water Dynamics

Soil Particle Size Classification : Soil texture is defined by sand (0.05–2.0 mm), silt (0.002–0.05 mm), and clay (<0.002 mm) content (Gee & Bauder, 1986), which strongly affects water storage and movement.

Water Retention : Clay holds more water but less is plant-available due to tight retention. Sand drains quickly with low retention, while silt offers balanced water storage (Rawls *et al.*, 1982).

Pore Size and Water Movement : Sandy soils have large pores for rapid infiltration; clay has small pores causing slow drainage. Silt provides moderate flow. Hydraulic conductivity is highest in sand and lowest in clay (Hillel, 1998; Jarvis *et al.*, 2013). Soil structure and organic matter can alter these patterns (Zhou *et al.*, 2008).

Water Availability:

- **Sand:** Low field capacity, low wilting point, low available water.
- **Clay:** High field capacity, high wilting point, moderate available water.
- **Silt:** Moderate-high field capacity, low wilting point, highest available water (Saxton & Rawls, 2006).

Land Use and Land Cover (LULC) Change in Humid Subtropics

Common Land Use Changes:

In humid subtropical regions like the Indo-Gangetic Plains and Eastern Ghats, natural areas are rapidly converted to agriculture (paddy, wheat, sugarcane) and urban spaces due to food demand and economic growth (Kumar *et al.*, 2019; Joshi & Kumar, 2020). Urbanization reduces fertile lands, while deforestation for timber and development degrades forest ecosystems (Singh *et al.*, 2022; Reddy, 2021). Water bodies are shrinking from siltation, encroachment, and drainage changes (Kumar *et al.*, 2019).

Drivers of Land Use Change:

Population growth, urban expansion, industrialization, agricultural intensification, and weak environmental enforcement drive rapid land conversion (Singh *et al.*, 2022; Kumar *et al.*, 2019; Reddy, 2021). Market forces and profitability also push farmers to shift cropping patterns or sell land (Joshi & Kumar, 2020).

Land Use Patterns :

Forests, agriculture, settlements, and water bodies define the humid subtropical landscape. Agriculture dominates, forests are degraded and fragmented, urban areas are expanding, and water bodies continue to decline, reflecting the competing pressures on land (Singh *et al.*, 2022).

Interlinkages: Land Use Change, Soil Texture, and Hydraulic Conductivity in Humid Subtropical India

Case Studies:

Land use changes (LUC) in humid subtropics impact soil texture and hydraulic conductivity (Ks), affecting water and ecosystem health. Forest-to-cropland conversion in the Terai region increased sand content (12–18%) and reduced Ks by 35–60% (Kumar *et al.*, 2020). In the Eastern Ghats, intensive farming on clay-loam soils raised bulk density by 15–25% and lowered Ks by 40–70% (Reddy *et al.*, 2021).

Interactive Effects of Texture and Management:

Coarse soils in Konkan showed a 50% Ks decline under continuous tillage (Patil & Sharma, 2022), while fine soils in Assam floodplains had a smaller Ks drop (20%), though compaction still reduced percolation (Das *et al.*, 2019). Conservation practices like zero-tillage and organic amendments improved Ks by 25–40% in Punjab's silt-loam soils (Singh *et al.*, 2021).

Texture-Specific Responses to LUC:

- **Lateritic Soils (West Bengal):** Plantation conversion increased coarse fragments (+22%), reducing Ks by 45% (Ghosh & Maiti, 2020).
- **Alluvial Soils (Indo-Gangetic Plains):** Urbanization reduced Ks by 50–80% due to topsoil compaction (Joshi *et al.*, 2022).
- **Red Soils (Eastern Ghats):** Shifting cultivation decreased clay (-14%) and Ks (-60%); agroforestry restored infiltration by 30% (Reddy *et al.*, 2021).

Methodologies for Assessing Changes

Field Measurement Techniques : Field methods like fixed plots, soil sampling, penetrometers, and infiltrometers provide accurate, ground-truthed data on compaction and hydraulic conductivity (Singh *et al.*, 2023). Tools like double-ring infiltrometers and Guelph permeameters offer precise infiltration and Ks measurements but are labor-intensive and best when combined with large-scale methods (Reynolds & Elrick, 1990).

Remote Sensing and GIS : Remote sensing (LANDSAT, Sentinel) enables broad monitoring of LULC changes using techniques like image differencing and spectral indices (e.g., NDVI, SAVI) (Vaudour *et al.*, 2022). GIS supports spatial modeling by integrating RS data with field measurements, aiding in erosion risk and land management assessments.

Soil Texture Analysis : Soil texture shifts (sand, silt, clay) influence water retention and erosion risks. Traditional (hydrometer, pipette) and modern (laser diffraction) methods assess particle size distribution (Bieganski *et al.*, 2018). Combining texture, infiltration, and RS-derived moisture data strengthens environmental monitoring and supports sustainable land management.

Implications for Water Resource Management and Agriculture

Irrigation Efficiency and Crop Productivity : Low soil hydraulic conductivity from land use change, compaction, or erosion increases runoff and deep percolation losses, lowering irrigation efficiency (Zhou *et al.*, 2008). Good soil structure and organic matter improve water storage, support higher yields, and reduce drought stress (Mohanty *et al.*, 2017). Poor land management raises irrigation demand, stressing local water resources (Lal, 1996).

Flood Control and Drainage Planning : Urbanization and soil compaction reduce infiltration, increasing runoff and flood risks (Yang & Zhang, 2011). Forested and well-managed lands improve

infiltration and reduce flooding (Fu *et al.*, 2000). Sustainable flood control requires integrating green infrastructure, soil management, and land zoning (Wang *et al.*, 2014).

Soil Conservation and Land Management : Practices like reduced tillage, cover cropping, and organic amendments enhance soil structure, infiltration, and fertility (Lal, 1996). Strategies such as afforestation, contour farming, and vegetative buffers control runoff and prevent soil degradation (Zhou *et al.*, 2008). These measures promote both agricultural sustainability and effective water management.

Conclusion

Soil hydraulic conductivity, closely linked to soil texture and land use change, plays a central role in water management, flood control, and agricultural productivity in humid subtropical India. Land conversions typically degrade soil structure, reducing infiltration and increasing runoff, but texture-specific responses and proper soil management can buffer these effects. Conservation practices, green infrastructure, and strategic land use planning are vital to sustaining soil health, improving irrigation efficiency, and enhancing climate resilience. Integrated field, remote sensing, and GIS approaches offer effective tools for monitoring and guiding sustainable land and water management strategies.

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AGRICULTURE 4.0: TRANSFORMING THE FUTURE OF FARMING THROUGH SMART TECHNOLOGIES

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Abstract

Agriculture is undergoing a revolutionary transformation, often referred to as Agriculture 4.0. This term represents the next phase in the evolution of agriculture, marked by the integration of cutting-edge technologies like the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, robotics, drones, and blockchain into farming systems. Unlike earlier revolutions which focused on mechanization and increased input use, Agriculture 4.0 emphasizes sustainability, precision, and data-driven decision-making. As the global population continues to rise and climate change threatens traditional farming, this new wave of technology promises to enhance productivity, reduce resource wastage, and build climate-resilient food systems. This article explores the concept, components, benefits, challenges, and implications of Agriculture 4.0, with particular attention to its relevance in developing countries like India.

Introduction

The agriculture sector is central to human survival, feeding over 8 billion people across the globe. Over the centuries, it has seen several significant transformations. The first was the domestication of plants and animals. The second came with the use of machinery and synthetic fertilizers during the Green Revolution. The third phase brought automation and biotechnology into the fold. Now, we are at the brink of the Fourth Agricultural Revolution or Agriculture 4.0, which is largely powered by digital technologies and intelligent systems (Abbasi *et al.*, 2022; Mondal *et al.*, 2024).

The need for this transformation is urgent. Traditional farming methods are becoming increasingly unsustainable due to the twin pressures of climate change and population growth. According to FAO estimates, the world will need to produce 60% more food by 2050 to feed the global population. At the same time, agriculture accounts for about 70% of global freshwater use and nearly 30% of greenhouse gas emissions. Clearly, a paradigm shift is necessary—one that focuses not just on more production, but better production.

Core Technologies Driving Agriculture 4.0

1. Internet of Things (IoT)

IoT in agriculture involves deploying smart sensors in fields to measure parameters such as soil moisture, temperature, humidity, and crop health. These sensors transmit real-time data to central systems, allowing farmers to monitor their farms remotely and make data-informed decisions. Smart irrigation systems, for example, can help save water by delivering the right amount at the right time (Rosem *et al.*, 2021).

2. Artificial Intelligence (AI) and Machine Learning

AI systems can analyze vast datasets to detect patterns, predict outcomes, and offer solutions. For instance, AI-powered applications can identify diseases in plants using image recognition, suggest treatment options, or even forecast pest attacks. Machine learning models can also optimize planting schedules, input use, and harvesting times based on predictive analytics (Rosem *et al.*, 2021).

3. Big Data Analytics

Every farm produces an enormous amount of data from weather reports and soil quality to input usage and yield records. Big data analytics helps convert this raw data into actionable insights. By analyzing trends and correlations, farmers can make more accurate and timely decisions that enhance productivity and profitability (Rosem *et al.*, 2021).

4. Robotics and Automation

Robots are increasingly being used in various stages of farming such as planting, weeding, harvesting, and even packaging. Autonomous tractors, robotic weeders, and milking machines are transforming labor-intensive operations into efficient and precise processes, reducing dependency on human labor (Rosem *et al.*, 2021).

5. Drones and Satellite Imaging

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are used for crop monitoring, spraying fertilizers or pesticides, and assessing field conditions. They provide aerial imagery that helps in identifying crop stress, water shortages, and pest infestations, allowing for early interventions (Rosem *et al.*, 2021).

6. Blockchain and Food Traceability

Blockchain technology ensures that every transaction or movement in the food supply chain is recorded in a transparent and immutable ledger. This is particularly useful in organic farming and high-value exports where certification, origin, and quality assurance are crucial (Rosem *et al.*, 2021).

Benefits of Agriculture 4.0

Agriculture 4.0 offers numerous advantages (Barman *et al.*, 2025), including:

- **Increased Efficiency and Productivity:** Automation and precision techniques lead to higher yields and reduced input costs.
- **Environmental Sustainability:** Smart farming helps conserve water, reduce pesticide use, and limit emissions, thus making agriculture more eco-friendly.
- **Better Resource Management:** Data-driven decisions ensure optimal use of land, water, seeds, and fertilizers.
- **Enhanced Livelihoods:** Access to real-time information and digital marketplaces can improve farm incomes and reduce post-harvest losses.
- **Climate Resilience:** Predictive models can help farmers prepare for weather changes, droughts, and other climate-related risks.

Challenges in Implementation

While the promise of Agriculture 4.0 is immense, its implementation faces several roadblocks (Maffezzoli *et al.*, 2022):

- **High Initial Investment:** The cost of advanced equipment and digital tools is often beyond the reach of small and marginal farmers.

- **Digital Divide:** Many rural areas still lack reliable internet connectivity and access to smart devices.
- **Lack of Technical Skills:** Farmers need training to understand and use digital tools effectively.
- **Data Privacy and Ownership Issues:** There is growing concern over who owns and benefits from the data collected on farms.
- **Policy and Institutional Gaps:** In many countries, there is a lack of coherent policies or support systems to promote digital agriculture at scale.

Agriculture 4.0 in India

India, home to over 120 million smallholder farmers, stands to gain immensely from Agriculture 4.0. The government has initiated several programs like the Digital Agriculture Mission (2021–2025) to promote smart farming through public-private partnerships (Barman *et al.*, 2025). Latest startups are using AI, IoT, and data analytics to solve critical problems in supply chains, market access, and farm management.

KVKs (Krishi Vigyan Kendras) and Agri-tech incubators are being encouraged to act as intermediaries in technology dissemination. However, scalability remains a challenge, and more efforts are needed in digital literacy, infrastructure, and customized local solutions.

The Road Ahead

To unlock the full potential of Agriculture 4.0, the following steps are essential:

- **Inclusive Policy Support:** Governments should provide subsidies or financial support to help farmers adopt new technologies.
- **Public-Private Partnerships:** Collaboration between technology providers, research institutions, and farmer cooperatives can accelerate adoption.
- **Capacity Building:** Training programs and extension services must focus on building digital literacy among farmers.
- **Infrastructure Development:** Rural internet connectivity, electricity, and mobile services need urgent expansion.
- **Localized Innovation:** Technologies must be tailored to local agro-climatic conditions, cropping patterns, and socio-economic contexts.

Conclusion

Agriculture 4.0 is not just about modernizing agriculture; it's about transforming the way we think about food production, environmental sustainability, and rural livelihoods. It offers a powerful toolbox for addressing the complex challenges facing agriculture today—from climate change and labor shortages to supply chain inefficiencies and food insecurity. However, for this transformation to be inclusive and equitable, there must be concerted efforts by all stakeholders—governments, research institutions, private companies, and farmers themselves. Only then can we ensure that Agriculture 4.0 becomes a catalyst for a greener, more resilient, and more prosperous agricultural future for all.

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BIOSTIMULANTS ROLE IN AGRICULTURE AND HORTICULTURE

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Abstract

Biostimulants are products that reduce the need for fertilizers and increase plant growth, ensure resistance to water and abiotic stresses. In small concentrations, these substances are efficient, favouring the good performance of the plant's vital processes, and allowing high yields and good quality products. In addition, biostimulants applied to plants enhance nutrition efficiency, abiotic stress tolerance and/or plant quality traits, regardless of its nutrient contents. Sagarika, a seaweed-based bio-stimulant, plays a significant role in both agriculture and horticulture by promoting plant growth, improving nutrient uptake, and increasing tolerance to environmental stresses. It's a valuable tool for sustainable agriculture, boosting crop yields, product *quality and farmer's profit* while minimizing reliance on chemical inputs. *This paper focusses on the roles and the right method of application (right quantity, right time and right method) of Sagarika to harness full benefits.*

Introduction

Biostimulants are natural or synthetic substances that can be applied to seeds, plants, and soil. These substances cause changes in vital and structural processes in order to influence plant growth through improved tolerance to abiotic stresses and increase seed and/or grain yield and quality. In addition, biostimulants reduce the need for fertilizers (Du Jardin 2015). Many definitions of biostimulants have been reported in the literature. According to Basak (2008), biostimulants could be classified depending on the mode of action and the origin of the active ingredient; while Bulgari et al., (2015) proposed biostimulants should be classified based on their action in the plants or, on the physiological plant responses rather than on their composition. In addition, Du Jardin (2015) has emphasized the importance of the final impact on plant productivity which suggests that any definition of biostimulants should focus on the agricultural functions of biostimulants, either on the nature of their constituents or on their modes of actions. Yakhin et al.,(2017) proposed the following definition of a biostimulant as a formulated product of biological origin that improves plant productivity because of the novel or emergent properties of the complex of constituents; and not as a sole consequence of the presence of known essential plant nutrients, plant growth regulators, or plant protective compounds. This definition is important as it emphasizes the principle that biological function can be positively modulated through the application of molecules, or mixtures

of molecules, for which an explicit mode of action has not been defined. In small concentrations, these substances are efficient, enhancing nutrition efficiency, abiotic stress tolerance, and/or crop quality traits, regardless of its nutrients content. These substances when applied exogenously have similar actions to the groups of known plant hormones, whose main ones are auxins, gibberellins, and cytokinins (Yaronskaya *et al.*, 2006).

Abiotic stress is a problem of concern for the growth and productivity of plants in modern times. Abiotic stresses, such as drought, salinity, and extreme temperatures, are responsible for huge crop losses globally (Singh and Takhur, 2018). In order to prevent these losses, biostimulants are increasingly being integrated into production systems with the goal of modifying physiological processes in plants to optimize productivity (Yakhin *et al.*, 2017). In general, biostimulants are produced as a junction of natural or synthetic substances composed of hormones or precursors of plant hormones. When applied correctly in the crops, it acts directly on the physiological processes providing potential benefits for growth, development, and/or responses to water stress, saline, and toxic elements, such as toxic aluminum (Du Jardin, 2012 and Couto *et al.*, 2012).

Sagarika: Importance in Agriculture and Horticulture

Plant bio-stimulants are products containing naturally occurring substances, microorganisms, or their synthetic equivalents that, when applied to seeds, plants, or the rhizosphere, stimulate natural processes to enhance crop yield. “Sagarika” is a seaweed based liquid and granular bio-stimulant consists of natural proteins, carbohydrates, essential plant nutrients and plant growth substances, that plays a significant role in both agriculture and horticulture by stimulating natural processes to enhance nutrient uptake, nutrient efficiency, tolerance to abiotic and biotic stresses which in turn boosts crop yield, product quality and farmer’s profit in both high yield modern agriculture and also suitable for organic farming. It enhances the seed germination and improves germination rates and seedling vigour. It is particularly known for boosting crop yields, improving root and shoot development, and promoting more flowering and fruiting. Sagarika also enhances the efficiency of both organic and chemical fertilizers and helps plants withstand abiotic stresses like drought, heat, and salinity. IFFCO Sagarika, a natural Seaweed based granular and liquid bio-stimulant is being produced by Aquagri Greentech Private Limited.

Sagarika Liquid is a concentrated liquid seaweed extract bio-stimulant which is from red and brown seaweed sap which naturally contains proteins, carbohydrates, inorganic salts/nutrients, vitamins, natural hormones (Auxin, Cytokinin, Gibberellins), betaines, mannitol etc. It is one of the most concentrated liquid seaweeds extracts available in the country. Its concentration is 28% w/w where the total solids are derived from the sap of both cultivated and collected seaweed in a proprietary proportion.

Key Features and Benefits of Sagarika

Sagarika-Seaweed Extract Concentrate is a plant-bio-activator manufactured through globally patented processes from red and brown marine algae. The product has naturally occurred plant growth regulators, essential amino acids, macro and micronutrients. Sagarika-seaweed extract concentrate when applied as foliar spray or the Rhizosphere, stimulates the metabolic function of the plant to enhance nutrient uptake and nutrient use efficiency leading to increase in crop yield and crop quality. Key Features of Sagarika (Liquid)

are given in **Table 1**.

Table 1. Key Features of Sagarika (Liquid)

Physico-chemical Parameters	Units	Specification
Total Soluble Solids (w/v)	%	28% (min)
Total organic matter	%	3.0 – 6.0
Solubility in water (30°C)	%	100%
pH (1% solution)	-	7.0 - 8.0
Total ash	%	23 - 25
Specific gravity @ 30°C	g/cc	1.1 – 1.2
Physical State		Conc. Liquid
Colour		Dark Brown Liquid
Salt Index		10
Macro nutrients		
Nitrogen (N)	%	0.1 - 0.30
Phosphorous (P)	%	0.05 - 0.1
Potassium (K)	%	8.0 – 8.5
Secondary nutrients		
Calcium (Ca)	%	0.15 - 0.30
Magnesium (Mg)	%	0.20 - 0.50
Sulphur (S)	%	1.5 - 3.0
Micro nutrients		
Zinc (Zn)	mg/L	5 – 12
Manganese (Mn)	mg/L	10 – 20
Sodium (Na)	%	1.0 - 3.0
Boron (B)	mg/L	4 – 6
Iron (Fe)	%	0.02 - 0.04
Silica (SiO ₂)	%	1.0 – 2.5
Copper (Cu)	mg/L	2.0 – 5.0
PGR like substances	mg/L	40-60
Total Amino Acids	%	0.2-0.3
Vitamins	mg/L	5 – 7.5

Sagarika as shown in **Picture 1** has been tested at different Agriculture Universities and ICAR research stations across 20 States of India covering all climatic zones and soil types of the country and found to increase crop yield and quality, increase microbial activity in the soil and gives plant the ability to withstand abiotic stress caused by drought and high salinity.

Sagarika is consisted of proteins, carbohydrates, inorganic salts /nutrients, vitamins, natural hormones, auxin, cytokinin, gibberellins, betaines, mannitol etc. is considered as organic plant growth promoter, yield enhancer, crop immunity enhancer etc.

The major benefits of Sarika are being mentioned below:



Picture 1. Sagarika granule and liquid

- **Better Seed Germination** : Sagarika improves seed germination rates and seedling vigour.
- **Reduced Transplant Shock** : It helps plants recover quickly after transplanting, minimizing stress.
- **Improved Plant Growth** : Sagarika enhances root and shoot development, leading to stronger, more vigorous plants.
- **Enhanced Flowering and Fruiting** : It promotes more flowering and fruiting, resulting in higher yields.
- **Enhanced Yield and Quality** : Sagarika promotes better plant growth, leading to increased yields and improved quality of produce in various crops.
- **Improved Nutrient Use Efficiency** : It enhances the plant's ability to absorb nutrients from the soil, making fertilizers more effective.
- **Increased Stress Tolerance** : Sagarika helps plants withstand adverse environmental conditions like drought, heat, and salinity, which is crucial for sustainable agriculture.
- **Soil Health** : It stimulates beneficial soil microbial activity, contributing to overall soil health and fertility.
- **Organic and Eco-Friendly** : Being derived from seaweed, Sagarika is a sustainable and environmentally friendly option for enhancing crop production.
- **Suitable for Various Crops** : It can be used on a wide range of crops, including field crops, plantations, pulses, oilseeds, and horticultural crops.

Specific Applications:

- **Field Crops**: Rice, wheat, sorghum, bajra, etc.
- **Plantations**: Arecanut, coconut, coffee, rubber, tea, etc.
- **Pulses**: Red gram, green gram, black gram, etc.
- **Oilseeds**: Groundnut, sesame, soyabean, castor, mustard, linseed etc.
- **Horticultural Crops**: Banana, apple, citrus, guava, mango, etc.
- **Easy Application**: Sagarika can be applied through foliar sprays or soil drenching, making it convenient for farmers. By incorporating Sagarika into agricultural and horticultural practices, farmers can achieve higher yields, improve crop quality, and enhance the sustainability of their farming system.
- **Packaging** : 100ml/250ml/500ml/1000ml/5000ml. Customized packing can be done based on need of the market/region.
- **Compatibility**: Sagarika-Seaweed Extract Concentrate is compatible with most insecticides, fungicides and fertilizers. Some pH adjustments may be required with acidic mixtures. Add surfactant after the product has completely dissolved in the tank solution. When mixing calcium products, thoroughly mix Sagarika liquid with the water in the tank prior to adding the calcium product. If interaction of chemicals is unknown, a "Jar Compatibility Test" is recommended.
- **Storage and Handling**: This product contains a preservative but should be stored away from direct sunlight and heat. Avoid spillage as product is very slippery and may create a hazard. Keep out of reach of children.
- **Directions for Use: Sagarika**- Seaweed extract concentrate fully dissolves in water and is suitable for foliar application. To achieve the desired results, the levels of major and minor nutrients must be adequate to support desired yield. The recommended application rate is 500 ml per acre. The application should be done with dilution of 125 L of water per acre. The

number of foliar sprays depends on crop needs and soil health. Preferably Sagarika spray should be done at tillering, pre flowering and post flowering stages and during any kind of abiotic stress such as drought, extreme heat, salinity etc. For best results apply Sagarika liquid should be applied in the forenoon or during afternoon around 3 PM to avoid extreme temperature during summer. In winter it can be applied any time in the day avoiding dew on the leaves. Do not spray just before or after rainfall or sprinkler irrigation. Use a mild rate of surfactant for maximum dispersal and leaf adherence. Application protocol for various methods of application is given in **Table 2**.

Table 2. Application Protocol for Sagarika

Sagarika- Seaweed Extract – Application Protocol				
S.No	Method of Application	Dosage	Application Protocol	Application Schedule
1	Foliar Application	500 ml/Acre	At the rate of 5.0ml per Lite of water	Pre-Flowering Stage Flowering Stage Maturity Stage
2	Fertigation	500 ml/Acre	Should be diluted between 0.25-0.5 %	Along with Irrigation Cycle
3	Drip Irrigation	500 ml/Acre	Should be diluted between 0.25-0.5 %	Along with Irrigation Cycle
4	Hydroponics	1ml/L	Add the 0.1% Sagarika solution to your reservoir	Regularly at 15-20 days interval
5	Root Dip	0.05%	Dip the roots for 10 minutes	Before Transplanting
6	Seed Treatment	0.10%	Soak the Seed for 10-30 minutes	Before Sowing

Application Protocol of Sagarika Liquid for Hydroponics

Rate : 1 ml per litre (at the rate of 0.1% (v/v)).

Frequency : Critical and grand growth stages.

Sagarika Z ++ - Seaweed Granules – Technical Data Sheet

Description: Sagarika Z++ is a red and brown marine alga fortified granule for application in agriculture. The alga is being cultivated and naturally collected from the Indian coast and thus become a source of livelihood for the fishermen families. Seaweed extract functions as a metabolic bio enhancer as it contains proteins, carbohydrates & other inherent nutrients, vitamins, plant growth promoting substances like Auxin, Cytokinin, Gibberellins, Glycine Betaines, Mannitol etc. Technical data related to Sagarika Z ++ seaweed granules is given in **Table 4**.

Table 4 Sagarika Z ++ - Seaweed Granules – Technical Data Sheet

Physicochemical Parameters	Units	Specification
Total organic matter (seaweed)	%	8.0 – 10.0
pH (1% solution)	-	5.0 - 7.0
Moisture content	%	8.0 – 10.0
Bulk density	g/cc	1.0 – 1.2
Total ash	%	80 – 85

Physicochemical Parameters	Units	Specification
Macro nutrients		
Nitrogen (N)	%	0.01 - 0.02
Phosphorous (P)	%	0.02 - 0.05
Potassium (K)	%	0.1 – 0.3
Secondary nutrients		
Calcium (Ca)	%	14 – 16
Magnesium (Mg)	%	5 – 7
Sulphur (S)	%	8 – 10
Micronutrients		
Zinc (Zn)	%	0.7 - 1.0
Boron (B)	%	0.15 – 0.25
Manganese (Mn)	mg/kg	500 – 800
Sodium (Na)	%	0.2 - 0.4
Iron (Fe)	%	0.50 – 3.00
Silica (SiO ₂)	%	4 – 6
PGR like substances	ppm	5 – 10
Total Amino Acids	%	0.01 – 0.02
Vitamins	ppm	2 – 5

Note: Sagarika Z++ is a natural product. Its properties may vary between batches and seasons hence above technical data analysis are presented in range format. Sagarika Z++ - Seaweed granule is certified for use in organic farming by IMO Control and Ecocert India. Sagarika Z++ is applied @ 10 kg/acre (25 kg/ha) as soil application as and topdressing.

The Road Ahead

Agricultural biostimulants may contribute to make agriculture more sustainable and resilient. Biostimulant treatments of agricultural crops have the potential to improve plant resilience to environmental perturbations. In order to fine-tune application rates, biostimulant-plant specificities and techniques are identified that may yield the highest impact on stress protection; high priority should be given to better understanding of the causal/functional mechanism of biostimulants.

Although input-producing companies are investing in the development of such new products for the incorporation of biostimulants and additives to agriculture each year, it can be observed from studies carried out that little is known about the mechanisms of action of these inputs in order to optimize the real gains from the incorporation of these products into agricultural production. In addition, there is a need to address the underlying mechanisms responsible for these effects, given the large number of substances that can be used as biostimulant raw material, such as humic substances, seaweed extracts, plant hormones, and plant growth-promoting rhizobacteria. The application of an appropriate biostimulant can improve root and shoot vigor, however, the selection of the appropriate biostimulant is critical as the effects can vary markedly between species.

Concluding Remarks

Sagarika, a seaweed based bio-stimulant, is produced by Aquagri Processing Private Limited in liquid and granular form which play a significant role in enhancing yield and farmer benefits of both agricultural and horticultural crops by promoting plant growth, improving nutrient uptake, and

increasing tolerance to environmental stresses. It's a valuable tool for sustainable agriculture, boosting crop yields and quality while minimizing reliance on chemical inputs. Sagarika contains various natural components like proteins, carbohydrates, plant growth regulators (auxins, cytokinin, and gibberellins), and essential nutrients, which collectively contribute to its beneficial effects. These components stimulate plant metabolic functions, leading to improved growth and stress resilience. Sagarika can be applied to a wide range of crops, including, cereals, pulses, oilseeds, vegetables, fruits, plantation crops, ornamental crops. It is available in both liquid and granular forms, offering flexibility in application methods.

This smart product is suitable for both modern agriculture and also for organic farming. Major benefits of Sagarika may be listed as : enhanced germination rate and reduces transplant shock, leads to better and stronger root growth, boosts plant growth, tillering and branching, fruiting and seed setting and quality enhancement of fruits/seeds and increases plants' natural defences against environmental stress, increases tolerance to abiotic stress such as drought, heat, salinity stress, increases nutrient use efficiency of organic and chemical fertilizers by the plant, provides stress relief to crops and enhances immunity against pests and diseases, enhances farmers benefit with increase in yield and quality of produce, and activates soil microbial population and improves soil health. Due to improved health, Sagarika is suitable for rainfed-dryland farming, climate resilient agriculture and for enhancing productivity of pulse, oilseeds and smaller millets crops.

In essence, Sagarika acts as a valuable tool for farmers and horticulturists, promoting sustainable and productive agricultural practices by enhancing plant growth, improving nutrient utilization, and increasing resilience to environmental challenges.

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TRANSFORMING AGRICULTURE THROUGH AI : BETTER YIELDS, SMARTER MARKETS

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Introduction

Agriculture has traditionally been a labor-intensive and weather-dependent sector. However, the 21st century marks a paradigm shift with the integration of Artificial Intelligence (AI) into the agricultural ecosystem. From precision farming to price forecasting, AI is not only boosting yields but also enabling smarter, data-driven decisions in markets. With global challenges like climate change, resource scarcity, and food insecurity, the digital transformation powered by AI offers a promising solution for sustainable and profitable agriculture.

What is Artificial Intelligence in Agriculture?

Artificial Intelligence in agriculture refers to the application of machine learning, computer vision, robotics, and data analytics to improve efficiency in farming. AI systems process large volumes of data from weather sensors, soil tests, satellite imagery, and market trends to make real-time decisions.

Key Components:

- **Machine Learning (ML):** Predictive modeling for yields, pests, etc.
- **Computer Vision:** Identifying weeds, crop diseases, or maturity through image processing.
- **Drones and IoT:** Real-time monitoring of crop health and soil conditions.
- **Natural Language Processing (NLP):** Interfaces like chatbots for farmers.

AI for Better Yields: Precision Agriculture

Precision agriculture uses AI to tailor farming practices according to the specific needs of a plot or even an individual plant.

1. Soil Health Monitoring

AI analyzes satellite and sensor data to monitor soil moisture, nutrient levels, and pH balance.

Example: *CropIn*, an Indian agri-tech startup, uses AI to generate real-time advisories for soil fertility.

2. Pest and Disease Prediction

AI models predict pest outbreaks and suggest optimal pesticides, reducing crop losses and environmental damage.

Case Study: Microsoft's AI Sowing App in Andhra Pradesh increased yield by 30% by advising the right sowing date.

3. Smart Irrigation

AI-powered sensors and weather data help in delivering the right amount of water, saving resources.

Data Point: According to *NITI Aayog (2021)*, AI-based irrigation can reduce water usage by 30–40%.

AI in Crop Management and Harvesting

1. Growth Monitoring : Drones equipped with AI evaluate crop canopy, height, and color to assess growth and stress levels.

2. Yield Forecasting : AI models can predict the quantity of produce weeks before harvest, helping farmers plan storage and marketing.

3. Autonomous Harvesting : Robotic harvesters use AI to identify ripe fruits and vegetables, reducing labor dependency.

AI for Smarter Markets

Beyond production, AI revolutionizes post-harvest processes and marketing.

1. Price Forecasting : AI analyzes historical price trends, weather, and demand-supply data to predict market prices.

Example: IBM Watson helps cooperatives and FPOs forecast vegetable prices in real time.

2. Supply Chain Optimization : AI identifies bottlenecks in transportation and storage, reducing wastage.

3. Market Linkages and E-Commerce : AI platforms match farmers with buyers based on quality, quantity, and price.

Example: *DeHaat* uses AI to connect farmers to input suppliers and output buyers across India.

Economic Benefits of AI in Agriculture

- **Increase in Yield:** 20–30% rise reported in pilot AI projects in India (NASSCOM, 2022).
- **Reduction in Input Costs:** Efficient use of water, fertilizer, and pesticides.
- **Minimizing Post-Harvest Losses:** Smart cold chains and storage.
- **Better Price Realization:** Direct market linkages reduce middlemen.

Challenges in Implementation

1. Infrastructure Deficiency : Lack of high-speed internet and electricity in rural areas.

2. Skill Gap : Most farmers are not digitally literate to use AI-based tools.

3. Data Privacy & Ownership : Who owns the data collected by sensors and apps—farmers or companies?

4. High Initial Cost : AI devices like drones, sensors, and robots are expensive for small farmers.

Government and Private Sector Initiatives

1. Government Programs

- **Digital Agriculture Mission (2021–2025)**
- **India Digital Ecosystem for Agriculture (IDEA)**

2. Private Sector Role

- **AgNext:** Uses AI for quality testing of food grains.
- **Fasal:** Offers AI-based weather and irrigation alerts.

Quote: “Public-private partnerships are crucial for scaling AI in agriculture.” – *FAO, 2021*

Future of AI in Agriculture

Key Trends:

- **AI-Powered Agribots**

- Blockchain with AI for traceability
- AI in climate-resilient crop breeding
- AI+Satellite for real-time national crop mapping

Vision 2030:

- Precision agriculture for all major crops.
- AI-powered insurance and credit risk models.
- Fully digitized agri-market platforms.

Conclusion

AI is transforming agriculture from intuition-based to information-based decision-making. While challenges persist, its potential for improving yields and enabling smarter markets is immense. The integration of AI in Indian agriculture, supported by policy, education, and private sector innovation, could be the key to achieving doubling farmer income, ensuring food security, and fostering climate-smart agriculture.

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THE ART OF KOKEDAMA: A GUIDE TO CREATING MOSS BALL PLANTERS

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Introduction

The term "moss ball," or kokedama, refers to a ball of moss-covered soil that is mostly utilized as a decorative plant and is native to Japan. Whereas "dama" implies ball, "koke" denotes moss. The centuries-old art of Kokedama is linked to the bonsai technique. The origins of bonsai can be traced back to the Chinese art of penjing, which involves constructing miniature landscapes using rocks and trees. The long-term process of cultivating and molding tiny trees in a container is the main emphasis of bonsai art. In addition to encouraging the audience to think about the piece, the artwork aims to motivate the grower to be persistent, hardworking, and imaginative.

Japanese culture has adopted the natural ability to express emotions via the beauty of flowers, plants, and nature in general. The Japanese people's unity with nature is demonstrated through intricate symbolism associated with Shinto and Buddhism, the country's two primary religions. More than 80% of people practice Shinto, making it the more popular of the two religions. In order to provide a bridge between the ancient past and the present, the Japanese ethnic religion known as Shinto (Shinto, "way of the gods") places a strong emphasis on rites that must be faithfully carried out. Buddhism has always had a significant impact on the Japanese people. Its teachings emphasize meditation and life experiences over inherited knowledge or theory, such as those contained in the scriptures.

The "kokedama" technique is taking a root from a plant and allowing it to grow from a ball of mud coated in moss. In the plant exhibit, the moss ball acts as the focus point for a sculpted tree or plant. The ball of moss and dirt is then attached to a platform or suspended from a rope, and the plant emerges from it. Whether strung on a string garden or mounted on a platform, it is essentially a living planter that can be arranged in a variety of ways. A unique way to develop nurturing skills. Without a pot, kokedama is a hanging plant that is arranged in a mass ball. It isn't completely new because hanging plants or even hanging gardens—like the Babylonian hanging gardens—were known for millennia. The kokedama itself was not formed recently; rather, it was made during the Edo era (1603-1868).

Plant Selection

Select plants that develop slowly or have modest root systems. Also, think about where your kokedama will sit or hang. The following species are suitable: angel hair vine, spider plant, mint, orchids, dwarf plant variants, and others.

1. Kokedama is best served by the epiphytic plant. Pothos (*Pothos scandens*) is a great choice due to its lovely foliage and manageable growth. Epiphytic plants will also quickly adapt because they are used to growing on other species. Ex- *Ageratum houstonianum*, *Amaranthus tricolor*, *Ficus lutea*, *Ficus natalensis*, *Ficus benhalensis*, etc.



2. **Succulents** are a great option for kokedama because they don't grow quickly and don't mind being dry. Semi-succulent or ex-zebra cactus. Ex- *Haworthiopsis fasciata*, (*Haworthia*) *H. aeonium* (*Haworthia* plant), *Echeveria elegans* (*Echeveria*), *Crassula ovata* (*Jade plant*), *Sansevieria trifasciata* (*snake plant*).



3. The finest plants for kokedama are ferns. Due to their resistance to low humidity. We suggest rabbit's foot fern or blue star fern. Ex- *Nephrolepis exaltata* (*Boston fern*), *Adiantum raddianum* (*Maiden hair fern*), *Phlebodium aureum* (*Blue star fern*), *Asplenium nidus* (*Bird's nest fern*), and *Platycerium bifurcatum* (*Staghorn fern*).



4. **Croton**: Select plants that can withstand sunshine if you wish to put your kokedama next to windows. Crotons typically grow large, but you can manage their development. Don't fertilize; just trim the roots and put them in a limited area. Ex- *Codiaeum variegatum* (*Gold Dust croton*).



Other plants use in kokedama

Common Name	Scientific Name
Spider Plant	Chlorophytum comosum
Rhoeo plant	Rhoeo discolor
Adenium Plant	Adenium obesum
Aglonema	Aglonema spp.
Calathea	Calathea spp.
Dieffenbachia	Dieffenbachia spp.
Coleus	Coleus blumei
Fittonia	Fittonia verschaffeltii
Peace lily	Spathiphyllum cochlearispathum
Poinsettia	Poinsettia puicherrima
Kalanchoe	Kalanchoe blossfeldiana
Syngonium	Syngonium podophyllum
Zebrina \Inch plant	Zebrina pendula
Asparagus	Asparagus spp.
Cryptanthus	Cryptanthus diversifolius
Excoecaria	Excoecaria bicolor
Monstera	Monstera deliciosa
Dracaena	Dracena spp.
Philodendron	Philodendron spp.
Ophiopogon	Ophiopogon jaburan
Hoya/ Wax vine	Hoya carnosa
Button fern	Hemionitis rotundifolia
Ostrich fern	Matteuccia struthiopteris
Man fern	Dicksonia antarctica
Autumn Fern	Dryopteris erythrosora
Lemon Butter Fern	Nephrolepis cordifolia 'Duff'
Crown of thorns	Euphorbia milii
Elephant bush	Portulacaria afra
Parsley	Petroselinum crispum
Christmas cactus	Schlumbergera x buckleyi
Aloe	Aloe vera
String of beads	Senecio rowleyanus
Peperomia	Peperomia obtusifolia
Prayer plant	Maranta leuconeura
Cyclamen	Cyclamen spp.
Grape ivy	Cissus rhombifolia
Jacob's ladder	Polemonium caeruleum
Oregano plant	Origanum vulgare
Basil	Ocimum basilicum
Donkey's tail	Sedum morganianum

How To Make Kokedama

Materials: Waxed twine or fishing line, potting soil, sphagnum sheet moss, peat moss, gloves, a bowl, and a measuring cup



Making the soil ready: Measure out 2 cups of potting soil in a bucket or bowl to form a 4-inch ball.



Wetting the soil: Apply more water later if necessary, but moisten the potting soil gradually until it just holds together when squeezed firmly



Forming the soil ball: form the soil ball, tightly pack the soil mixture into a ball. This will ensure that it holds together when thrown into the air a few times.



Plant preparation: Take the plant out of its pot and shake off as much dirt as you can.



Planting the plant in the soil ball: Shake the plant carefully to remove as much soil as possible after removing it from its pot. Inserting the plant into the soil ball: Place the plant's roots in the center of the ball after dividing it in half. After that, carefully press the soil ball around the plant.



Preparing the moss: To prepare the sphagnum moss for wrapping around the soil ball, dampen it with warm water to make it malleable. Place the soil ball in the middle of the sheet moss, face down, and collect the moss around the soil and up to the plant.



Ready to be kokedama: Now that the moss ball is prepared for kokedama, it can be tied to hold everything together.



Wrapping the moss ball: Moss ball wrapping: Use fishing line or monofilament string to hold the moss ball in place during wrapping. Using one hand, begin wrapping the ball, leaving a long tail at the bottom to tie off when you're finished. Wrap in all directions. Wrap the ball from top to bottom, leaving a long tail, then tie the ends to hang your kokedama. If you would rather not hang your Kokedama, you can display it in a shallow dish.



Care of Kokedama: Kokedama should be soaked in a small basin of water for five to ten minutes, or until it becomes heavy, in order to treat it. As often as the ball feels light, usually every several days, repeat. Add a water-soluble fertilizer to the water bowl every several weeks. If the plant has grown too large and is starting to show signs of stress in spite of your best efforts to water and fertilize it, you may need to move it to a larger ball.



Importance of Kokedama : Japanese plant art, or kokedama, has various significant features.

The Value of the Environment

1. **Sustainable:** Kokedama is environmentally benign because it needs less water and soil.
2. **Low Maintenance:** Watering less frequently saves resources and minimizes waste.

Cultural Importance

1. **Japanese Heritage:** Kokedama's origins in Japan are indicative of the country's close ties to the natural world.
2. **Meditative Practice:** Developing and maintaining kokedama promotes serenity and mindfulness.

Aesthetic Worth

1. **Unique Beauty:** The colorful moss and spherical form of Kokedama make for an eye-catching display.

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2. **Decorative Flexibility:** Decorative Flexibility: Different designs can be made using a variety of plants, mosses, and materials.

Value of Education

1. **Botanical Knowledge:** Kokedama imparts knowledge on soil composition, plant growth, and moisture management.
2. **Creative Expression:** Kokedama promotes trying with various materials, mosses, and plants.

Health Advantages

1. **Air Purification:** Kokedama uses plants to help filter the air.
2. **Stress Relief:** Taking care of kokedama helps ease tension and encourage rest.

Versatility

1. **Indoor/Outdoor Use:** Kokedama may grow well in a variety of settings.
2. **Adaptability:** Different materials and plants can be utilized to accommodate different sunlight and climates.

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SWAYAM: A DIGITAL BRIDGE TO INCLUSIVE AND LIFELONG LEARNING IN INDIA

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Introduction

In an era where digital technology is transforming education globally, India has taken a significant leap with the launch of the SWAYAM platform—an ambitious initiative aimed at bridging the digital divide in access to quality education. Whether you are a school student, a university learner, a working professional, or even a progressive farmer, SWAYAM offers a gateway to free, structured, and credible learning opportunities anytime, anywhere (Kumar and Mahendrapabu, 2021).

What is SWAYAM?

SWAYAM (Study Webs of Active–Learning for Young Aspiring Minds) is a Massive Open Online Course (MOOC) platform developed by the Ministry of Education, Government of India. Launched in 2017, SWAYAM aims to provide accessible and affordable education to every Indian learner, particularly those in remote or rural areas (Mahaldar, 2023).

The platform offers online courses across disciplines like science, technology, humanities, agriculture, education, and management, developed by India's top institutions like IITs, IIMs, IGNOU, and ICAR.

Table 1: Key Features of SWAYAM

Feature	Description
Free Access	Courses, videos, and materials are available free of cost to all users.
Multilingual Content	Many courses offered in Hindi, English, and regional languages.
Expert Faculty	Courses are created and taught by national-level experts and professors.
Certification Option	Learners can opt for paid exams and receive certificates from UGC/AICTE-recognized institutions
Flexible Learning	Learn at your own pace, with pre-recorded lectures and downloadable materials
Credit Transfer	UGC-approved credit transfer for SWAYAM courses in affiliated universities.

SWAYAM for Agriculture and Rural Learners

SWAYAM is particularly valuable for students and professionals in agriculture and allied sectors, offering:

- Courses on agronomy, soil science, agricultural economics, animal husbandry, and more.
- Modules on entrepreneurship, agribusiness management, ICT in agriculture, etc.
- Content developed by ICAR, MANAGE, IGNOU, and agricultural universities.
- Opportunity for young farmers, FPO members, and extension workers to access expert knowledge without leaving their villages.

How SWAYAM Works: Step-by-Step

- Register for Free at <https://swayam.gov.in>
- Browse and choose a course relevant to your field or interest
- Start learning through video lectures, readings, and quizzes
- Join discussion forums to interact with peers and instructors
- Appear for an optional exam at a designated centre (for certification)

Advantages of SWAYAM (Paul *et al.*, 2018)

- **Inclusivity:** Breaks barriers of geography, gender, and economy—anyone with internet access can learn
- **Skill Enhancement:** Supports upskilling and re-skilling for students, teachers, professionals, and self-employed youth.
- **Support for NEP 2020:** Encourages flexible curricula, credit-based learning, and digital empowerment.
- **Bridging Urban–Rural Divide:** Rural learners can access the same content as IIT and IIM students.

Table 2: Challenges and Solutions

Challenge	Solution
Digital illiteracy in rural areas	Conduct training and awareness through KVKs, CSCs, and NGOs
Poor internet connectivity	Offline downloads, mobile access, and rural broadband initiatives
Language and complexity barriers	More regional language content, simplified teaching methods
Limited awareness	Mass outreach campaigns via radio, TV, schools, and panchayats

Initiatives Linked with SWAYAM

- **SWAYAM PRABHA:** 34 DTH TV channels telecasting educational content 24x7 for those without internet.
- **DIKSHA:** Complementary platform for school-level teachers and learners.
- **MOOC Credit Framework:** UGC allows up to 40% of a semester's credits to be earned via SWAYAM.

The Way Forward

To ensure SWAYAM's widespread adoption and impact:

- KVKs, agricultural universities, and NGOs should promote SWAYAM courses in rural areas.
- State governments must integrate SWAYAM into agricultural training and youth development schemes.
- Extension personnel can act as digital facilitators in villages.
- Integration with Smart Villages, FPOs, and SHGs can scale outreach and application

Conclusion

The SWAYAM platform symbolizes India's digital revolution in education, democratizing access to world-class knowledge across disciplines. For the agricultural community, it offers not just courses, but a ladder to empowerment, skill development, and informed decision-making. By embracing

SWAYAM, we move a step closer to inclusive, quality education for all, in alignment with the Sustainable Development Goals and NEP 2020.

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AGRIVOLTAICS: THE FUTURE OF SUSTAINABLE FARMING AND ENERGY CO-PRODUCTION

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Abstract

Agrivoltaics is gaining traction as a potential solution to the rising obstacles of land scarcity, energy demand, and climate change. On the same piece of land, solar energy generation and agricultural activities work together to produce food and electricity synergistically. This dual-use strategy adds clean energy to the grid while regulating agricultural microclimates, conserving water, and boosting farmer income. Case studies from China, India, France, the United States, and Japan demonstrate that crops may flourish under solar arrays, typically with increased yield or quality. Recent developments in technology and policy are paving the way for broader adoption, despite hefty setup costs and concerns regarding crop compatibility. Agrivoltaics has the potential to be an integral part of climate-smart, resilient farming systems that strike a balance between sustainability and productivity, provided they have the proper support.

Keywords: Agrivoltaics, photovoltaics, solar panel and sustainable energy.

Introduction

With climate change accelerating and fertile land becoming scarce, farmers and researchers are searching for innovative ways to grow food and energy more efficiently. Solar sharing or agrivoltaics is a solution that is increasingly making headlines globally. This cutting-edge practice sees the same land used for cropping and generating solar energy at the same time.

Agrivoltaics refers to the co-location of solar photovoltaic (PV) facilities along with the dual benefit of agricultural production. It has emerged as a game-changing approach to resolving land-use conflicts between food security and energy production. This method increases resource efficiency, reduces climate footprint, and boosts rural economies. The panels are installed high enough to allow crops to grow beneath them, creating a half-shaded microclimate that shields plants from excessive heat (Fig 1). At the same time, the solar panels generate electricity for on-farm consumption or the local power grid. Initially developed in Japan in the early 2000s, the concept has gained global adoption, with significant uptake in France, Germany, the USA, and India.

Shading rate is the percentage of shade produced by the PV panels, calculated as follows.

$$\frac{\text{Total area of panels}}{\text{The area of farmland where the frames are installed}} \times 100 \text{ [\%]}$$

In solar sharing setups, about 30–35% of sunlight is typically blocked by solar panels. But since every crop has its own light requirements, the setup is carefully tailored to match its needs. So, the shading

rate is adjusted depending on what is being grown, ensuring both the plants and the panels can thrive together.

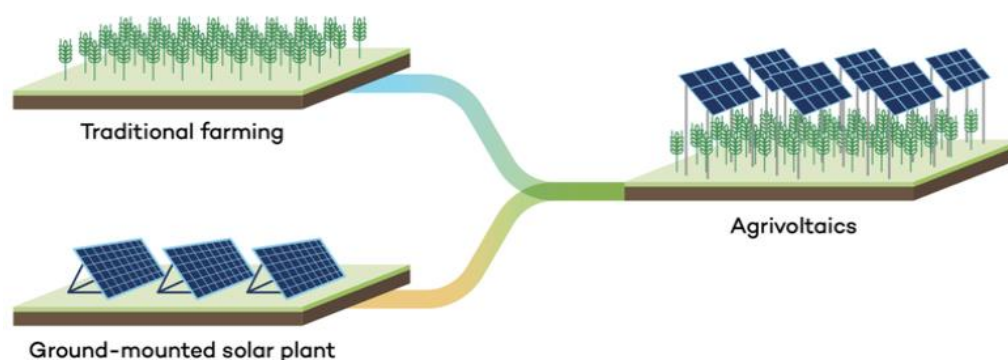


Fig 1: Illustration of a typical agrivoltaics system (Source:IISD, 2023)

Below, we explore the benefits, challenges, and prospects of agrivoltaics, drawing insights from peer-reviewed research and case studies.

Benefits of Agrivoltaics

- **Water Efficiency:** Shade helps reduce soil moisture loss, which cuts down on irrigation—a major plus in arid regions. Reduced evapotranspiration cuts irrigation needs by as much as 20–30%, essential in water-deficient areas (Santhosh, 2025).
- **Land Efficiency:** The land equivalent ratio (LER), a measure of comparison of dual-use efficiency, tends to be greater than 1.0. Under certain desert conditions, it has even gone up to 1.6 and beyond, demonstrating that agrivoltaics is more land-efficient compared to farming or solar power alone (Dupraz *et al.*, 2011).
- **Better Income Generation:** Farmers can diversify income sources and minimize financial risk through selling electricity or renting out land for photovoltaic panels.
- **Enhanced Crop Yield:** In arid zones, PV panels are responsible for forming microclimates that reduce soil temperature and preserve moisture. For instance, in Jodhpur, India, trials recorded 30–40% increased bean and vegetable yields (IISD, 2023).
- **Energy Production:** 300–400 homes annually can be powered by a 1 MW agrivoltaic facility while the land remains for farm use. (Santhosh *et al.*, 2025)
- **Climate Mitigation:** Greenhouse gas emissions are reduced by displacing fossil fuels and it promotes carbon sequestration through healthier soils.

Challenges and Constraints

- **High Initial Costs:** The Specialized infrastructure cost of installing Agrivoltaic systems is 20–30% more.
- **Crop Compatibility:** Shade-tolerant crops (e.g., leafy greens, berries, turmeric, etc) thrive, while sun-loving crops (e.g., wheat) may suffer yield losses.
- **Policy and Awareness Gaps:** Pilot programs are still small-scale in places like India, where adoption is hampered by a lack of standardised rules and farmer training. Without dedicated frameworks, it can be more difficult to obtain permits or subsidies for agrivoltaics since it frequently lies between the areas of energy and agriculture policy.

The primary concern is that agricultural production might be negatively impacted by shade. However, studies indicate that partial shadow from solar panels might be advantageous for some

crops, particularly those that are heat-sensitive. It protects plants from heat stress, reduces water evaporation, and occasionally even boosts harvests. Vegetables like lettuce, spinach, and tomatoes thrive in these kinds of environments, according to studies. (Barron-Gafford *et al.*, 2019).

Case Studies in India

- The Central Arid Zone Research Institute (CAZRI), Rajasthan: 1-acre, 105 kWp pilot in Jodhpur powering drip irrigation and rainwater harvesting. Crops like brinjal, okra, pulses, and gourds showed improved yield.
- Project by company Harsha Abakus Solar implemented a 666 m²/25 kWp project in Bhuj, Gujarat, at two sites (1.0 MWp/4.50 acres each) in the Jamnagar and Kutch districts.
- Another successful initiative was the 1 MW agrivoltaic project in Maharashtra, where panels installed over onion and chilli fields resulted in minimal yield loss and additional farmer income (MNRE, 2023).
- Cochin International Airport Ltd (CIAL), Kerala: 20 acres, 4MW, on which vegetables such as yam, long yard bean, drumstick, mountain ginger, turmeric, cabbage, cauliflower, and green chilli are cultivated. Uses solar panel cleaning water for irrigation; enhances microclimate and panel efficiency.
- PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) Scheme supports 500 kW–2 MW solar/RE plants on farmland with a 10 GW national target to boost farmer income and energy access.

Global Case Studies

- **France:** AgroPV project over vineyards improved grape quality via heat moderation (Weselek *et al.*, 2019). Sun'Agri's 84 kWp AI-driven system in Piolenc reduced vine water requirement by 13–34% and, boosted anthocyanins by 13% and acidity by 9–14% (Sun'Agri, 2021).
- **United States:** The National Renewable Energy Laboratory (2024) reported that 10 GW of agrivoltaic capacity across 62,000 acres that supports crops like tomatoes and pollinator habitats. Also, Cornell University has initiated trials for lettuce, spinach, radishes, strawberries and raspberries, and plans to install a 300kW system for apple trees (Gashler, 2025). A collaborative project between the University of Arizona and local farmers showed that tomatoes under panels used less water and tolerated heat better; also panels stayed cooler and more efficient (Barron-Gafford *et al.*, 2019).
- **Japan:** One of the first countries to explore agrivoltaics. The government has allowed the co-use of farmland for solar generation since 2013. Chiba Ecological Energy Inc. operates a one-hectare demonstration farm in East Tokyo cultivating potatoes, ginger, and eggplant beneath 2,826 elevated panels. The system generates around 830,000 kWh annually (Akimaru, 2018).
- **China:** Baofeng Group developed a 1 GW solar park in Ningxia Province, an arid region, with goji berries farming (Bellini, 2020). In Zhejiang Province, 200 MW Jiangshan Agrivoltaic Park combines solar panels with shade-tolerant herbs (e.g., *Dendrobium orchids*) and livestock zones. They restored degraded land while generating clean energy for 113,000 households (CASE, 2025).
- **Italy:** Pontinia Solar Farm (70 MW) in Lazio olive groves and saffron with bifacial solar panels, dedicating 65% land to farming while powering 47,000 homes (CASE, 2025).

Future Thrust Areas

- **Technological Innovations:** Bifacial panels and dynamic mounting systems that absorb sunlight on both sides, adjustable tracking systems that follow the sun, and smart sensors that adjust to crop needs are under development.

- **Policy Integration:** Subsidies, land-use zoning reforms, and energy-sharing frameworks (e.g., Solar Power Europe's collective self-consumption models) could accelerate adoption.
- **Research Priorities:** Long-term studies on soil health, crop diversity, and scalability are needed to optimize system designs.

Conclusion

Agrivoltaics is not just a clever use of space—it's a forward-thinking way to meet two essential human needs at once: food and energy. By maximizing land use and minimizing environmental impact, this model offers a powerful tool for sustainable development. As governments, researchers, and farmers continue to collaborate, agrivoltaics could help build a greener, more resilient agricultural future.

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SPIDER VENOM: A SUSTAINABLE APPROACH FOR BIO-INSECTICIDE DEVELOPMENT AND PEST CONTROL

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Abstract

The projected increase in the global human population to 9.3 billion by 2050 is expected to place significant pressure on food production, necessitating innovative pest management strategies. Herbivorous insects remain a major challenge, reducing crop yields despite extensive chemical control efforts. However, the overuse of chemical insecticides has led to insecticide resistance and raised environmental and health concerns. As a result, there is a growing need for eco-friendly alternatives such as bio-insecticides. Spider venom, with its complex mixture of neurotoxins, enzymes, and peptides, presents a promising avenue for bio-pesticide development.

Keywords: Spider venom, Bio-insecticides, Pest control.

Introduction

The global human population is expected to grow to 9.3 billion by the year 2050 (Bloom, 2011). The growing population will place significant strain on food production, as there is limited potential to expand cultivated land. Even with strict control efforts, herbivorous insects continue to diminish global crop yields (Boyer *et al.*, 2012). Currently, chemical insecticides are the primary method used to manage arthropod pests that impact agriculture and public health. However, the extensive application of these agrochemicals has created genetic selection pressure, leading to the emergence of insecticide-resistant arthropods, along with growing concerns about their effects on human health and the environment (Windley *et al.*, 2012). Worries over the negative effects of certain types of chemical insecticides on both the environment and human health have resulted in numerous deregistration and discontinuations of their use (Herzig *et al.*, 2014). It is essential to adopt environmentally friendly pest control strategies, such as the use of bio-insecticides, with spider venom being one of the most effective methods.

Spiders are ancient organisms that originated from an arachnid ancestor approximately 300 million years ago, during the Carboniferous period. This emphasizes the extensive evolutionary history through which spiders have developed their intricate venom systems. As the most diverse venomous animals, spiders, alongside predatory beetles, are among the most successful terrestrial predators, with over 42,000 living species documented so far (Windley *et al.*, 2012). One of the key factors behind the success of spiders is their ability to produce potent venom from specialized glands, which they use to capture prey and defend against predators. As obligate predators, spiders

have developed a sophisticated and diverse mix of enzymes, neurotoxins, and cell-damaging substances within their venom, honed through evolution. Spider venom is acidic, with pH levels typically ranging from 5.3 to 6.1. This acidic environment is mainly due to the presence of organic acids, particularly citric acid, which is the most commonly reported organic acid in spider venom (Kuhn-Nentwig *et al.*, 2011). Nevertheless, being venomous doesn't automatically mean that spiders pose a threat to humans. In fact, only about 0.5% of all known spider species have been identified as potentially harmful to humans (Hauke & Herzig 2017). Therefore, based on the truth spiders primarily use their venom to subdue insect prey, a clear potential use for venom components, such as venom peptides, is in the creation of new bioinsecticides (Klint *et al.*, 2012).

Ideal characters of bioinsecticides

The ideal eco-friendly bioinsecticide should effectively target insects through ingestion or direct contact, remain stable under harsh environmental conditions, and provide rapid action to incapacitate or eliminate pests. It should be non-toxic to humans and other vertebrates, including birds and fish, while also being safe for beneficial insects like pollinators and natural predators. Additionally, it should not accumulate in the environment or break down into harmful by-products.

Components of spider venom

Spider venom components are generally categorized into four main groups:

- (1) Small molecular mass compounds (SMMCs).
- (2) Antimicrobial peptides (found in only a few spider families).
- (3) Peptide neurotoxins.
- (4) Proteins and enzymes.

Small molecular mass compounds (SMMCs): Small molecular mass compounds (SMMCs) are believed to occur in the majority of spider venoms. These compounds consist of ions, organic acids, nucleotides, nucleosides, amino acids, amines, and polyamines (Kuhn-Nentwig *et al.*, 2011). For example, the venoms of *Cupiennius salei* and *Aphonopelma hentzi* from the Theraphosidae family are characterized by high potassium concentrations (around 200 mM and 70 mM, respectively) and low sodium levels (approximately 10 mM) (Savel-Niemann & Roth, 1989). These cation levels contrast with those found in haemolymph. The elevated potassium content in the venom is believed to cause depolarization of excitable cell membranes, resulting in prey paralysis, while also working synergistically to boost the effectiveness of venom peptides (Wulschleger *et al.*, 2005).

Antimicrobial peptides

Antimicrobial peptides (AMPs), also known as cytolytic or cationic peptides, typically have a strong positive charge and contain a significant amount of hydrophobic amino acids. They are widely found as key elements of animal immune systems and can also be found in the venoms of various arthropods, including ants, scorpions, bees, and wasps (Kuhn-Nentwig, 2003). AMPs disrupt the integrity of cellular membranes of the organisms.

Proteins and enzymes

For a long time, enzymes and proteins were thought to play a minor role in spider venoms. These include hyaluronidases, which break down hyaluronan in the extracellular matrix, collagenases, which target collagen, and phospholipases, which hydrolyse phospholipids in the cell membrane (Binford *et al.*, 2009). In the venom gland, proteins potentially involved include protein disulfide isomerases, peptide isomerases, carboxypeptidases, and newly discovered 28 kDa serine proteases,

which are responsible for cleaving properties from immature toxin precursors. Additionally, other proteins like those with leucine-rich repeat domains or tachylectin 5A-like proteins, which resemble immune-active proteins found in related spider species, might play a role in protecting the venom gland from microbial infections (Kuhn-Nentwig *et al.*, 2019). Proteins that likely target critical systems in prey may include large neurotoxic proteins, an acetylcholinesterase that breaks down the neurotransmitter acetylcholine at synapses, or an α -amylase, which is thought to induce hyperglycaemia in prey by rapidly releasing large amounts of glucose from glycogen stores (Undheim *et al.*, 2013).

Peptide neurotoxins

Neurotoxic peptides affect a wide variety of channels and receptors on the membranes of excitable cells, such as nerves and muscles. These peptides are relatively small, usually consisting of 30–40 amino acids, and a single spider's venom can contain over 1,000 distinct peptides (King and Hardy, 2013). Neurotoxic peptides create stable complexes with channels or receptors and are effective even at nanomolar concentrations. As a result, these peptides can produce toxic effects at concentrations that are at least ten times lower than those required for non-selective toxins, like AMPs. However, the impact of these toxins can vary depending on the prey type, the specificity of the neurotoxins for particular channels, and the receptors present in the prey (Vassilevski *et al.*, 2009).

Arrangement of Venom Delivery System in Spiders

Spiders have a pair of fangs connected to their chelicerae, which they use to inject venom when biting. In mygalomorph species, the venom glands are confined to the chelicerae, whereas in araneomorph species, the glands may extend into the cephalothorax, taking up a considerable portion of its volume (Nentwig & Kuhn-Nentwig, 2013). The fangs, functioning like hypodermic needles, typically open at the tip and move in one of two directions: dorsoventrally in mygalomorphs or mediolaterally in araneomorphs. The venom glands are encased in striated muscle, which is controlled by the nervous system. This enables the spider to release venom through muscular contractions of the gland at its own will (Malli *et al.*, 2000).

Application strategies:

Spider venom peptides have potential applications in the development of bio-pesticides and can be introduced into plants as transgenes. This would enable the crops to produce their own pesticides, offering protection against pests (King and Hardy, 2013). The Nc1a peptide found in the venom of the *Nephila clavata* spider is a newly identified insecticidal toxin effective against cockroaches. It works by inhibiting the NaV and KV channels in cockroaches. As a result, Nc1a peptides from spider venom could serve as a model for developing bio-pesticides (Jin *et al.*, 2017). The SF11/GNA fusion protein, derived from snowdrop lectin and spider venom, has been shown to reduce the growth and reproductive capacity of aphids (*M. persicae*). When this fusion protein was incorporated into their food, 100% mortality was observed after seven days, attributed to the slowed developmental rate of the aphids (Down *et al.*, 2006). The Hvt peptide from the *H. versuta* spider exhibits toxic effects on two aphid species, *Aphis gossypii* and *Myzus persicae* (Shaheen, 2017).

Conclusion

Spider venom represents a valuable resource for the development of bio-pesticides, offering a sustainable alternative to chemical insecticides. With their sophisticated venom systems honed through millions of years of evolution, spiders have evolved potent toxins that target various insect

species. Venom components, such as neurotoxic peptides, show great promise in addressing the challenges posed by agricultural pests while minimizing environmental and health risks. By harnessing these natural compounds, it is possible to create bio-insecticides that are effective, environmentally friendly, and capable of slowing down the rise of insecticide resistance. Future research and development should focus on further understanding the properties of spider venom and translating this knowledge into practical pest management applications, such as transgenic crops and targeted bio-pesticides.

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SMART FARMING WITH DRONES: A TECHNOLOGICAL LEAP IN MODERN AGRICULTURE

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Introduction

The agricultural landscape is rapidly evolving due to the integration of smart technologies, especially Unmanned Aerial Vehicles (UAVs), commonly known as drones. These flying devices, when equipped with sensors, GPS, and imaging tools, serve as critical assets for precision agriculture. Drones offer an efficient, data-driven approach to monitor, manage, and optimize farming operations, marking a shift from intuition-based to evidence-based decision-making. This article explores the scientific principles, applications, advantages, constraints, and policy implications of drone technology in agriculture.

The science behind agricultural drones

Agricultural drones utilize a combination of the following technologies:

- **Remote sensing:** Through multispectral, hyperspectral, and thermal imaging, drones detect variations in crop health, moisture levels, and pest infestation.
- **Geographic Information Systems (GIS):** Map-based analytics enable precision targeting of interventions.
- **Global Navigation Satellite Systems (GNSS):** Drones navigate farm boundaries and execute GPS-tagged tasks with high accuracy.
- **Machine Learning and AI:** Real-time data analytics help identify crop stress, predict yield, and classify field zones.

These tools together enable **site-specific crop management (SSCM)**—a core tenet of precision farming.

Applications of Drones in Agriculture

a) Crop monitoring and health assessment

- **NDVI (Normalized Difference Vegetation Index)** and **SAVI (Soil Adjusted Vegetation Index)** maps reveal plant vigor.
- Early detection of nutrient deficiencies, fungal infections, or drought stress allows timely corrective measures.

b) Precision spraying

- Drones can be used for **variable-rate application** of fertilizers, pesticides, and micronutrients.
- Reduces chemical usage by 20–30% and ensures uniform application.

c) Soil and field analysis

- Topographic mapping helps assess soil texture, slope, erosion-prone zones, and water-logging areas.
- Elevation models assist in designing efficient irrigation layouts.

d) Planting and seeding

- Specially equipped drones can shoot seed pods directly into the soil, aiding in afforestation and cover cropping.

e) Crop surveillance and insurance

- Drone imagery is used for estimating crop damage, yield forecasting, and **claim verification** under schemes like **PMFBY (Pradhan Mantri Fasal Bima Yojana)**.

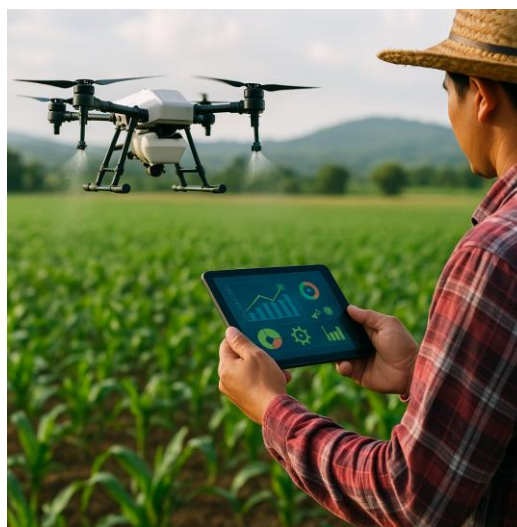


Figure 1: Foliar spray application through drones

Table 1: Advantages of drone technology in farming

Benefit	Scientific Impact
Faster data collection	Real-time decisions, precision interventions
Reduced input costs	Less wastage of seeds, water, and agrochemicals
Environmental sustainability	Minimizes runoff, leaching, and chemical residues
Farmer safety	Limits exposure to hazardous chemicals during spraying
Climate resilience	Enables drought monitoring and post-disaster assessments

Constraints and challenges

Despite its promise, drone technology faces several hurdles in Indian agriculture:

- **High initial cost:** Commercial drones range from ₹3 to ₹10 lakh depending on payload and sensors.
- **Skill gap:** Requires trained pilots, data analysts, and agronomists.
- **Battery and payload limitations:** Flight duration and tank capacity restrict scalability on large farms.
- **Regulatory compliance:** Permission for BVLOS (Beyond Visual Line of Sight) operations still restricted.
- **Data privacy and connectivity:** Dependence on stable GPS and 4G/5G networks.

Future prospects and research directions

- **Swarm drones:** Multiple drones coordinating autonomously for large-scale spraying.
- **AI-powered crop models:** Integration with weather data and phenological models for early warnings.

- **Drone-AI-blockchain nexus:** For real-time monitoring, traceability, and market linkage.
- **Hybrid drones:** Solar-powered and extended-range drones for remote farming zones.

Conclusion

Drones represent the next frontier of smart farming, offering science-based, scalable solutions to modern agricultural challenges. With the right blend of policy support, digital infrastructure, and local capacity building, drone technology can revolutionize Indian agriculture by improving productivity, profitability, and sustainability. As we aim to double farmer income and ensure climate-resilient agriculture, drones will not just fly over farms—they will drive transformation on the ground.

EFFECTS OF SHRIMP FARMING EFFLUENTS ON WATER QUALITY IN A TROPICAL ESTUARY

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Abstract

Shrimp farming has rapidly expanded across tropical regions often discharging untreated or partially treated effluents in to adjacent estuarine ecosystems. This study examines the effects of these effluents on the water quality of tropical estuaries focusing on parameters such as salinity alteration, nutrient enrichment, dissolved oxygen (DO) fluctuations, and proliferation of phytoplankton. Findings indicate the effluent discharge leads to the elevated levels of nitrogen, phosphorous, resulting in eutrophication and hypoxic conditions that threatens the aquatic biodiversity. Additionally organic matter and salinity fluctuations disrupt natural balance of estuarine environment affecting both micro and macro faunal communities.

Keywords: Shrimp farming effluents, eutrophication, water quality management, Algal blooms

Introduction

Shrimp aquaculture is one of the fastest growing economic activities in coastal areas of the Asia-Pacific region, where 72% of the world's farmed shrimp are produced. Shrimp farms cause environmental impacts in coastal ecosystems, compromising water quality by discharging effluents rich in nutrients and organic matter. The impacts of shrimp farming are often investigated by the unit effect of a farm. However, the main impact of shrimp farms is caused by discharge of effluents during daily water exchange and harvest, when shrimps are removed after reaching commercial size. These effluents contain high concentrations of nutrients, suspended solids and organic matter causing depletion of dissolved oxygen and increasing water turbidity. Water exchange operations can also modify the morphological balance of coastal systems, especially when it occurs synchronously with tidal oscillation. Factors such as location, management, and stocking density influence shrimp farm effluent quality and degradation levels. Adjustments in discharges according to estuary residence time and tidal regime can mitigate the impacts of the activity.

Impacts of Effluents of Shrimp Farming on Estuaries

Shrimp aquaculture has become a cornerstone of coastal economies in many tropical regions. However, its rapid expansion has raised environmental concerns, particularly regarding the discharge of nutrient rich effluents in to estuarine ecosystems. These effluents comprising uneaten feed, shrimp waste, antibiotics and chemicals can significantly affect the physical, chemical and biological integrity of estuarine waters

1. Nutrient Loading and Eutrophication:

One of the most pressing impacts is nutrient enrichment. Effluents from shrimp ponds are often high in nitrogen and phosphorus, which stimulate excessive algal growth. This process, known as eutrophication, can lead to oxygen depletion (hypoxia), harming fish, crustaceans, and other aquatic

organisms. By using hydrodynamic modeling found that nutrient concentrations were highest in areas with low water velocity, where pollutants tended to accumulate. With low water velocity, where pollutants tended to accumulate.



Figure 1. Extensive algal bloom resulting from excess nutrients from shrimp farm effluents in the Jaguaribe River Estuary, Northeast Brazil. (Luiz Drude de Lacerda, 2021).

2. Alteration of Water Quality Parameters:

Shrimp farm discharges also affect key water quality indicators such as pH, salinity, turbidity, and dissolved oxygen, researchers observed statistically significant differences in suspended solids and phytoplankton composition between intake and effluent waters. Cyanotoxin-producing species were found at concentrations five times higher in effluent samples, raising concerns about ecological and public health risks.

3. Seasonal and Tidal Influences:

Interestingly, the timing of effluent discharge plays a role in mitigating impacts. The same 2021 study showed that synchronizing harvest-related discharges with spring or neap tides helped reduce nutrient buildup in upper estuarine zones. This suggests that strategic waste management, aligned with natural tidal cycles, can lessen environmental stress.

4. Long-Term Ecological Consequences:

Beyond immediate water quality degradation, shrimp farming can lead to long-term ecological shifts. Persistent nutrient loading and habitat alteration may reduce biodiversity, simplify food webs, and impair the resilience of estuarine systems. In some cases, even after farms are decommissioned, residual impacts, such as soil salinization and mangrove loss continue to affect ecosystem recovery.

Impact of Shrimp Farming Effluents on Water Quality and advanced modeling techniques to assess the water quality in the Potengi–Jundiaí Estuary, Brazil

The Potengi–Jundiaí Estuary (PJE) in northeastern Brazil is a vital tropical estuarine ecosystem. It supports biodiversity and sustains local livelihoods but is increasingly threatened by anthropogenic pressures namely urban development, industrial discharge, and expanding shrimp aquaculture. Shrimp farms are located along the extension of PJE. This report examines the effects of shrimp

farming effluents on estuarine water quality using advanced modeling and scenario analysis. This case study examines the effects of shrimp waste discharges, compares them with other pollution sources, and explores potential mitigation strategies. While agricultural runoff, industrial waste, and urban sewage are known contributors to water pollution, shrimp farming has become an additional stressor, particularly in regions with slow water circulation.

Shrimp farm effluents contribute to water quality degradation by increasing nitrogen, phosphorus, and organic matter levels in estuarine waters. This can lead to eutrophication, where excess nutrients cause algal blooms that deplete oxygen, disrupting aquatic ecosystems. In low-flow areas, particularly in the upper estuary, these wastes accumulate over time, raising long-term pollution concerns. Although urban and industrial waste discharges introduce more pollutants than shrimp farms, aquaculture still significantly affects localized water quality. As a result, marine biodiversity, including fish populations, suffers due to reduced oxygen levels and increased water turbidity, further impacting the ecological balance of the estuary.

Advanced Modelling Techniques Used to Assess the Water Quality in the JPE; Brazil

The Jundiaí-Potengi Estuary (JPE) in Brazil has been studied using advanced modeling techniques to assess water quality and pollution dynamics. Hydrodynamic models simulate water movement and tidal influences, while biogeochemical models analyze nutrient cycling and pollutant dispersion. Numerical simulations predict sediment transport and contamination levels, integrating geochemical and ecotoxicological data to assess environmental risks. Multivariate statistical techniques help classify pollution sources and distinguish between natural and anthropogenic influences. Remote sensing provides large-scale monitoring capabilities, tracking land-use changes and algal blooms. Additionally, machine learning enhances predictive models for estuarine health, refining pollution forecasting and environmental assessments. These models together offer valuable insights into the effects of industrial and agricultural runoff on estuarine ecosystems, supporting sustainable management and conservation efforts.

The Impact of Shrimp Pond Effluent on Water Quality of Vasishta Godavari Estuary [VGE]

The River Godavari is India's second longest river after the Ganga. At Dowaleswaram (16°56'59.99" N 81°44'59.99" E) it bifurcates into two main distributaries called Vasishta Godavari and Gowthami Godavari. Vasishta Godavari is the western distributary of the Godavari, flows about 90 km from Dowaleswaram emptying into the Bay of Bengal at Antervedi. Physicochemical studies were carried out to predict whether the variations are due to seasonal changes or due to aquaculture effluents in Vasishta Godavari Estuary (VGE). Towards this objective water samples were collected in VGE from five stations during Oct-2016; Monsoon with Farm Period (FP)-1 discharge, Jan-2017; Postmonsoon with FP-2 beginning, June-17; Premonsoon with FP-3 discharge. Shrimp farming effluents significantly affect water quality in the Vasishta Godavari Estuary, primarily through changes in salinity, dissolved oxygen levels, biochemical oxygen demand, total suspended solids, and chlorophyll-a concentrations.

- Discharges from aquaculture introduce organic matter and excess nutrients, leading to oxygen depletion, increased turbidity, and eutrophication that can result in algal blooms. Seasonal and tidal variations play a crucial role in dispersing pollutants, with semi-diurnal tides helping to mitigate localized contamination, while monsoonal freshwater influx influences salinity gradients.

- Although natural estuarine processes assist in diluting effluents, persistent discharge from shrimp farms can create pollution hotspots, affecting aquatic life and ecosystem stability.
- Hydrodynamic and biogeochemical modeling have been utilized to assess the impact of shrimp pond effluents, simulating water movement, nutrient cycling, and pollutant dispersion.



Figure 2. Impacts of the algal blooms on local species

Shrimp farming, a lucrative sector in aquaculture, has grown rapidly over the past few decades, particularly in coastal regions where estuaries and lagoons provide ideal conditions. However, this expansion has led to significant environmental concerns, primarily stemming from effluents discharged into surrounding water bodies. These effluents contain excess nutrients, organic matter, antibiotics, and suspended solids, which can degrade water quality and disrupt ecosystems. To address these challenges, researchers and industry experts have developed various mitigation strategies, ranging from advanced treatment systems to integrated aquaculture techniques. This document explores multiple approaches that can help minimize the ecological footprint of shrimp farming while maintaining its economic viability.

MITIGATION STRATEGIES FOR SHRIMP FARMING EFFLUENTS

1. Effluent Treatment Systems: Enhancing Water Quality Before Discharge:

Effluent treatment plays a critical role in reducing the environmental impact of shrimp farming. Before wastewater is released into natural ecosystems, several filtration and purification techniques can help remove contaminants.

- **Sedimentation Ponds:** Shrimp farms often produce water rich in suspended solids, which can lead to turbidity and sedimentation in nearby rivers and coastal areas. Sedimentation ponds allow heavy particles to settle, preventing excessive organic loading downstream.
- **Mechanical Filtration :** Physical filtration methods, such as mesh screens and sand filters, can remove solid waste before effluent reaches natural water sources. These systems prevent waste buildup and improve water clarity.
- **Biofloc Technology:** Biofloc systems introduce beneficial bacteria and plankton that consume organic waste, improving water quality while providing a supplementary feed

source for shrimp. This approach reduces the need for water exchange and minimizes pollution.

- **Chemical Treatment with Coagulants:** Coagulants like aluminum sulfate can be used to aggregate suspended solids, facilitating their removal through sedimentation. While effective, chemical treatments must be carefully managed to avoid secondary contamination.

2. Nature-Based Solutions: Harnessing Ecosystem Services for Water Filtration

Natural ecosystems offer excellent filtration mechanisms, making them ideal for mitigating shrimp farming effluents.

- **Mangrove Restoration:** Mangrove forests act as natural biofilters, absorbing excess nutrients and stabilizing coastal environments. Their roots trap sediments and pollutants, preventing their spread into open waters.
- **Constructed Wetlands:** Artificial wetlands mimic natural filtration processes by promoting plant and microbial interactions that break down pollutants. These systems have been successfully implemented in several aquaculture regions.
- **Riparian Buffers:** Riparian buffers are **vegetated areas** located along the edges of streams, rivers, lakes, and other water bodies. These buffers play a crucial role in **protecting water quality, reducing erosion, and supporting biodiversity**. They act as a natural barrier between aquatic ecosystems and surrounding land, filtering pollutants, stabilizing banks, and providing habitat for wildlife.

3. Integrated Multi-Trophic Aquaculture (IMTA): A Symbiotic Approach to Waste Reduction:

IMTA involves cultivating multiple species within the same system, where organisms complement each other by utilizing different nutrients.

- **Seaweed Cultivation for Nutrient Uptake :** Excess nitrogen and phosphorus from shrimp farms can be absorbed by seaweed, reducing nutrient pollution. Certain seaweed species also provide economic benefits as food or biofuel sources.
- **Shellfish Filtration :** Filter-feeding mollusks like oysters and mussels help remove organic waste and excess algae, improving water clarity and reducing eutrophication risks.
- **Polychaete Worm Cultivation for Sediment Cleaning :** Polychaetes break down organic matter in sediments, enhancing overall pond health and minimizing sludge accumulation.

4. Best Management Practices (BMPs): Optimizing Farm Operations for Sustainability:-

Implementing effective farm management techniques can significantly reduce environmental impacts.

- **Feed Optimization :** Overfeeding leads to nutrient buildup and water pollution. Using high-quality, digestible feed and precise feeding schedules minimizes waste.
- **Aeration and Water Circulation Improvements :** Stagnant water creates conditions for harmful algal blooms. Proper aeration and water circulation enhance oxygen distribution and prevent excessive nutrient concentrations.
- **Biosecurity Measures to Prevent Disease Outbreaks:** Avoiding antibiotic overuse is crucial for maintaining environmental balance. Regular health monitoring and quarantine protocols help prevent disease spread without relying on chemicals.
- **Selective Breeding for Disease Resistance:** Genetically selecting shrimp strains with natural disease resistance reduces the need for antibiotics and chemical treatments.

Conclusion

Shrimp farming effluents pose significant environmental challenges, particularly in tropical estuarine ecosystems, where nutrient loading, organic matter accumulation, and altered water parameters disrupt ecological balance. However, sustainable mitigation strategies such as advanced filtration systems, nature-based solutions, and Integrated Multi-Trophic Aquaculture (IMTA) offer promising ways to minimize these impacts. By adopting best management practices (BMPs), optimizing farm operations, and utilizing hydrodynamic and biogeochemical modeling for informed decision-making, shrimp aquaculture can strike a balance between economic growth and environmental sustainability.

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SEAGRASSES IN INDIA : ECOLOGY, THREATS, AND CONSERVATION

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Abstract

Seagrasses are essential marine plants that are essential to the health of coastal ecosystems. The abundance of seagrass resources in India, their geographic range, and their ecological significance in promoting fisheries, biodiversity, and carbon sequestration are highlighted in this article. Despite their importance, human activity and climate change pose a number of threats to seagrass habitats. Current conservation initiatives to protect these priceless underwater meadows are also covered in the article.

Introduction

Seagrass, an oceanic flowering plant able to finishing its lifecycle completely submerged below the surface, is a dominating biological community along the planet's shallow coastal zones. This distinct and fertile coastal environment may be found in isolated coastal, backwater, lagoon, and estuary systems across India. It is correctly referred to as a biological sentinel because of its ability to reveal the state of ecosystem health; it is also referred to as an ecological engineer because of its function in changing and stabilizing the ecosystem (Thangaradjou and Bhatt, 2018). Seagrasses are among the world's most diverse landscape formations of shallow-water estuarine/marine environments (Boström *et al.*, 2006). Seagrass beds are among the most common and productive coastal ecosystem types on the planet, ranging from the tropics to the boreal edges of every sea. Seagrasses add physical structure to otherwise featureless sediment bottoms, hence increasing community diversity, biomass, and primary and secondary output (Duffy, 2006). Seagrass communities are critical to our climate and food security, yet they are relatively unexplored and on the fringe of marine conservation (Unsworth *et al.*, 2019).

Global carbon dioxide emissions from energy combustion and industrial processes increased to their greatest yearly level ever in 2021. Emissions increased by 6% from 2020 to 36.3 gigatonnes (Gt) (IEA, 2021). Carbon sequestration refers to the act of transferring and securely storing atmospheric CO₂ into other persistent C pools that could have been discharged or stay in the atmosphere. As a result, in this context, C sequestration might be a natural or artificial phenomenon (Lal, 2008). "Blue carbon" is often described as the organic carbon (OC) generated and retained by "coastal vegetated habitats" such as mangroves, seagrass meadows, and tidal salt marshes. These natural systems evolved as a result of certain terrestrial vascular plants adapting and colonizing coastal marine habitats (Miyajima and Hamaguchi, 2019).

Seagrass resources in India

India's 8000-kilometer coastline harbours seagrass in remote regions such as bays, open seas, estuaries, lagoons, and backwaters. The presence of seagrass in India has been documented since

the 1880s (Thangaradjou and Bhatt, 2018). As a tropical country, India has significant seagrass resources, with 15 species spanning around 500 square kilometers in isolated areas along the coast, lagoons, backwaters, and estuaries. The following are the 15 species found along the Indian coastline (Pande *et al.*, 2021):

Family- Hydrocharitaceae	Family- Cymodoceaceae	Family- Ruppiaceae
☐ <i>Enhalus acoroides</i>	☐ <i>Cymodocea rotundata</i>	☐ <i>Ruppia maritima</i>
☐ <i>Halophila ovalis</i>	☐ <i>Cymodocea serrulata</i>	
☐ <i>Halophila ovata</i>	☐ <i>Halodule uninervis</i>	
☐ <i>Halophila stipulacea</i>	☐ <i>Halodule pinifolia</i>	
☐ <i>Halophila beccarii</i>	☐ <i>Halodule wrightii</i>	
☐ <i>Halophila decipiens</i>	☐ <i>Syringodium isoetifolium</i>	
☐ <i>Halophila minor</i>		
☐ <i>Thalassia hemprichii</i>		

Fig. 1 Seagrass resources in India

Distribution of seagrass in India

The seagrass is distributed in the following parts of Indian coast (Pande *et al.*, 2021):

Gulf of Manner and Palk Bay, Tamil Nadu (Bay of Bengal) having an area of 6911 ha.	Andaman and Nicobar Island (Bay of Bengal) having an area of 1460 ha.	Lakshadweep Island (Arabian Sea) having an area of 72 ha.
Gulf of Kutch, Gujarat (Arabian Sea) having an area of 1700 ha.	Chilka Lake, Odisha (Bay of Bengal) having an area of 8547 ha.	

Fig. 2 Seagrass distribution across the Indian coast

Ecological Importance of Seagrass

Habitat and nursery for marine life

For many marine animals, such as fish, crabs, and molluscs, they offer vital habitat and nursery grounds. Higher biodiversity and survival rates are supported by the shelter and protection that seagrass beds' thick flora provides for young marine creatures (Ramesh *et al.*, 2019).

Role in carbon sequestration

Seagrasses' ability to sequester carbon is one of their most important ecological roles. These plants aid in slowing down climate change by absorbing and storing carbon dioxide from the atmosphere and ocean. According to estimates, seagrass meadows retain carbon in their sediments for extended periods of time, sequestering it at rates far higher than those of terrestrial forests. Seagrasses are therefore an essential component of worldwide initiatives to control atmospheric levels and fight climate change (Ramesh *et al.*, 2019).

Threats to Seagrass Ecosystems

Seagrasses are threatened in several ways, endangering their sustainability and health despite their significance. Degradation and habitat loss are the results of coastal development, including building and land reclamation. Algal blooms are encouraged by pollutants from agricultural runoff, such as surplus chemicals and fertilizers, which can suffocate seagrass habitats and degrade water quality (Ramesh *et al.*, 2019).

Conservation Efforts towards Seagrass

We may safeguard seagrass meadows and enhance the resilience of coastal ecosystems by putting into practice efficient conservation and management strategies. Creating Marine Protected Areas (MPAs) to protect seagrass ecosystems from damaging activities, enforcing laws to reduce nutrient pollution, and encouraging sustainable coastal development practices are all examples of effective conservation methods. Rehabilitating damaged regions and guaranteeing the long-term health of these ecosystems also depend on restoration initiatives like restoring seagrass beds and enhancing water quality (Ramesh *et al.*, 2019; Unsworth *et al.*, 2019).

Conclusion

Seagrass ecosystems are essential for marine life and coastal communities, but they are still one of the most at-risk habitats. They need urgent help to ease the stress they are under by protecting, restoring, and managing the coast in a way that is good for the environment. India has many important and diverse seagrass beds, so it is important to strengthen conservation efforts and raise awareness. These underwater ecosystems will be able to survive for a long time if people work together at the local, national, and global levels.

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THE ECONOMICS OF AGRICULTURAL LABOR SHORTAGES AND MECHANIZATION, INFLUENCED BY MIGRATION

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Abstract

The agriculture sector globally is experiencing a significant labor shortage due to rural-to-urban migration, aging populations, and the rise of non-agricultural employment opportunities. These changes, driven by both voluntary and involuntary migration, have accelerated the adoption of mechanization in various agricultural systems. This article explores the economic implications of agricultural labor shortages, the role of migration, and the consequent push towards mechanization. It analyzes cost structures, productivity impacts, policy dynamics, and the socio-economic trade-offs inherent in the mechanization transition.

Introduction

Agriculture continues to be a major source of livelihood, especially in developing countries. However, recent decades have witnessed an increasing decline in farm labor availability, particularly during peak agricultural seasons. This labor scarcity is being driven by rural-to-urban migration, demographic transitions, and rising non-farm employment. In response, farm mechanization has become not just a strategy for increasing productivity but a necessity for sustaining agricultural operations.

Migration and mechanization are two sides of the same economic transformation in agriculture. While migration pulls labor away from farms, mechanization fills the vacuum, offering higher efficiency and reduced dependency on seasonal workers. This article aims to understand the economic causes and consequences of this shift.

Drivers of Agricultural Labor Shortages

1. Rural-Urban Migration

Migration from rural to urban areas is a global phenomenon. According to the United Nations (2022), over 56% of the global population lives in urban areas, a number projected to rise to 68% by 2050. This trend directly impacts the labor supply in rural agriculture.

Economic Pull and Push Factors:

- **Pull factors:** Better wages, education, healthcare, and lifestyle in cities.
- **Push factors:** Low farm income, lack of infrastructure, land fragmentation, and climate stress in rural areas.

2. Demographic Changes

The aging rural workforce and the reluctance of the youth to engage in traditional agriculture contribute significantly to labor shortages.

3. Government Policies

Subsidies and incentives for urban industries and education have made rural farming less attractive. Additionally, the COVID-19 pandemic intensified reverse migration, but the long-term trend remains outmigration.

Economic Impacts of Labor Shortages in Agriculture

1. Increased Labor Costs

With limited labor availability, agricultural wages have increased. In India, for example, agricultural wages have grown at an average rate of 6–8% annually in real terms over the past decade (NABARD, 2020).

2. Delayed Agricultural Operations

Shortages during critical periods like sowing and harvesting result in productivity loss, crop damage, and increased post-harvest losses.

3. Shift in Crop Choices

Farmers are increasingly moving toward less labor-intensive crops, leading to changes in cropping patterns and regional imbalances in food production.

Rise of Mechanization in Response to Labor Shortages

1. Mechanization Trends

Mechanization is gaining pace, especially in middle-income countries. Tractor use, combine harvesters, rice transplanters, and threshers are increasingly replacing manual labor.

- In India, the number of tractors grew from 0.1 million in 1970 to over 7 million by 2020 (FAO, 2021).
- In China, agricultural mechanization increased from 30% in 2000 to over 70% by 2020 (MOA China, 2021).

2. Types of Mechanization

- **Land preparation:** Tractors, rotavators
- **Sowing and planting:** Seed drills, transplanters
- **Harvesting:** Combine harvesters, reapers
- **Post-harvest:** Threshers, dryers, shellers

3. Economic Rationale for Mechanization

- Fixed capital cost spread over years of use
- Reduced labor dependence
- Higher operational efficiency and precision
- Lower production costs in the long term

Economic Cost-Benefit Analysis of Mechanization

Aspect	Manual Labor	Mechanized Operations
Cost per hectare	High during peak season	High initial, low per hectare later
Time efficiency	Labor-intensive	Fast and consistent
Yield impact	Variable due to delays	Timely operations ensure better yield
Employment	High but seasonal	Lower labor need, but technical jobs created

Mechanization has a positive net present value (NPV) over time, especially in labor-scarce and large-landholding situations.

Role of Migration in Accelerating Mechanization

Migration acts as both a trigger and enabler of mechanization:

- **Trigger:** As youth leave farming, machines become necessary to maintain production.
- **Enabler:** Remittances from migrants are often invested in farm mechanization.

Case Study: India

States like Punjab and Haryana have high out-migration from rural youth and simultaneously lead the nation in mechanization levels. Migrant remittances have played a significant role in purchasing farm machinery.

Regional Examples

1. Sub-Saharan Africa

Labor shortages in some areas are leading to the adoption of small-scale mechanization tools like mini-tractors and ox-drawn planters.

2. South and Southeast Asia

Mechanization is rising rapidly due to urban migration. Thailand and Vietnam show mechanization levels above 70% in rice farming (IRRI, 2020).

Challenges in Mechanization

1. High Capital Costs

- Equipment is expensive for smallholders.
- Custom hiring centers (CHCs) and cooperatives are emerging to bridge this gap.

2. Fragmented Land Holdings : Small plots make mechanization less efficient unless land consolidation or cooperative farming is practiced.

3. Lack of Skilled Operators : There is a shortage of trained machinery operators and mechanics in rural areas.

Socio-Economic Trade-offs

1. Employment Impacts : While mechanization reduces labor demand, it also creates jobs in machinery production, maintenance, and operation.

2. Gendered Implications : Mechanization often reduces the role of female labor, especially in transplanting and weeding, unless gender-inclusive tools are developed.

3. Equity and Inclusion : Mechanization benefits larger farmers more, potentially widening rural inequalities unless policies ensure equitable access.

Government Policies and Supports

1. Mechanization Subsidies : Many countries offer 20–50% subsidies on farm equipment to encourage mechanization.

2. Custom Hiring Centers : In India, CHCs allow smallholders to rent equipment, making mechanization accessible.

3. Skill Development : Training programs for youth in agri-machinery operations improve both employment and mechanization outcomes.

Future Outlook

Mechanization is likely to accelerate further with technological innovations such as:

- AI and IoT in precision agriculture
- Robotics for harvesting and spraying
- Drones for monitoring and input application

As migration continues and labor becomes scarcer, the cost-benefit ratio of mechanization will become increasingly favorable, particularly when supported by smart financing, policy support, and inclusive infrastructure.

Conclusion

The intertwined dynamics of agricultural labor shortages, migration, and mechanization represent a structural shift in rural economies. While migration depletes the rural labor force, it also offers remittance-fueled opportunities for capital investment in farm mechanization. Mechanization, in turn, can sustain and improve agricultural productivity in the face of declining manual labor. However, for this transition to be equitable and sustainable, supportive policies, inclusive financing models, and gender-sensitive technology design are essential. The economic benefits of mechanization outweigh its costs in the long term, especially when guided by coherent policy and institutional support.

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TRICHODERMA: A PROMISING BIOCONTROL AGENT FOR SUSTAINABLE AGRICULTURE

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Abstract

The growing need for sustainable agricultural practices highlights the importance of biological control agents, with the filamentous fungal genus *Trichoderma* emerging as a leading candidate. *Trichoderma*'s have diverse modes of action, such as mycoparasitism, antibiosis, and resource competition, which contribute to its effectiveness in managing plant diseases. The historical development of *Trichoderma* as a biocontrol agent and the pressing demand for alternatives to harmful chemical pesticides are explored, reinforcing its vital role in advancing sustainable and eco-friendly agriculture.

Keywords: Trichoderma, Bio-control, Phytopathogens

Introduction

The increasing demand for sustainable agricultural practices has accelerated the exploration of eco-friendly alternatives to chemical pesticides, with *Trichoderma* species emerging as highly effective biological control agents due to their multifaceted benefits in plant health and disease suppression. These fungi form mutualistic associations with plants, offering numerous advantages in exchange for plant-derived sucrose, such as promoting plant growth, enhancing nutrient absorption, modifying the rhizosphere environment, and improving tolerance to both biotic and abiotic stresses. The excessive and unscientific use of chemical pesticides has led to serious environmental concerns and the development of resistant pathogen strains, highlighting the urgent need for safer alternatives like *Trichoderma*. *Trichoderma* spp. employ a variety of mechanisms to combat plant pathogens, including the production of antibiotics and diverse secondary metabolites, mycoparasitism, competition for space and nutrients, and the activation of plant defense pathways through the release of specific elicitors. These capabilities enable *Trichoderma* to parasitize a broad range of phytopathogens in the rhizosphere while also inducing systemic resistance in host plants. The exploration of *Trichoderma* as a biocontrol agent dates back to the early 1930s, and its successful commercial application across multiple crops underscores its potential in reducing reliance on synthetic agrochemicals. Given its exceptional ability to enhance plant growth, suppress diseases, and strengthen plant immunity, *Trichoderma* holds a pivotal role in integrated pest and disease management strategies in contemporary sustainable farming systems.

The most frequently sampled *Trichoderma* species include *T. harzianum*, *T. asperellum*, *T. atroviride*, *T. longibrachiatum*, *T. viride*, and *T. virens*. The first three species are well known as effective biocontrol agents, primarily using mycoparasitism and competition to combat fungal phytopathogens. In contrast, species such as *T. virens*, *T. longibrachiatum*, and *T. viride* use antibiosis as a powerful mechanism to combat a variety of plant pathogens.

Mechanism of antagonism

Trichoderma's biocontrol mechanisms provide effective plant protection through direct interactions with pathogens through mycoparasitism, competition, or antibiosis, as well as indirect interactions that enhance plant defense systems.

1. **Mycoparasitism:** Mycoparasitism is a central mechanism by which *Trichoderma* species inhibit fungal pathogens, often by killing and deriving nutrients from them, though some act as biotrophic parasites. The process involves three major stages: recognition of the host fungus, where oligochitins may serve as signaling molecules and genes for proteases and transporters are pre-activated; physical interaction, mediated by hydrophobin-like proteins forming appressoria-like structures; and degradation of host hyphae using lytic enzymes such as chitinases, glucanases, proteases, and other cell-wall degrading enzymes. The host responds with reactive oxygen species (ROS), to which *Trichoderma* activates stress-response and detoxification pathways. These enzymatic systems are also exploited in biotechnology for their potent lytic capabilities. Comparative genomic studies of *T. reesei*, *T. virens*, and *T. atroviride*—and their respective teleomorphs (*Hypocrea* spp.)—revealed high genetic conservation (up to 96%) and preservation of genes involved in antagonistic activity, suggesting mycoparasitism as an ancestral trait in the genus.
2. **Competition:** Antibiosis represents a key biological control mechanism by which *Trichoderma* spp. inhibit plant pathogens through the secretion of cytotoxic secondary metabolites. These compounds, include antibiotics and volatile organic compounds (VOCs), those are upregulated in response to pathogen presence or plant-derived signals, indicating a dynamic tripartite interaction among the plant, pathogen, and biocontrol agent. Over 180 bioactive metabolites have been identified in *Trichoderma* species, encompassing iron-chelating agents, growth promoters, plant defense inducers, and antifungal agents. For instance, *T. virens* produces trichodermamides, and *T. koningii* synthesizes koninginins, both known for antimicrobial properties. In *T. harzianum* and *T. virens*, additional metabolites such as azaphilones, viridins, harzianopyridone, and harzianic acid have been implicated in antagonism against fungal pathogens. Furthermore, *Trichoderma* species secrete a suite of lytic enzymes—including chitinases, glucanases, and proteases—that degrade pathogen cell walls. Notably, the VOC 6-pentyl-2H-pyran-2-one (6-PP), produced abundantly by *T. atroviride*, not only exhibits antifungal activity but also promotes plant growth by regulating sugar transport in *Arabidopsis* roots. These multifaceted biochemical capabilities underscore *Trichoderma*'s potential as an effective biocontrol agent in sustainable agriculture.
3. **Antibiosis:** The rhizosphere, enriched by plant root exudates such as amino acids, sugars, and organic acids, serves as a competitive hotspot compared to bulk soil. Microorganisms inhabiting this zone must exhibit strong metabolic efficiency and competitive traits to secure niche dominance. *Trichoderma* species thrive in this environment by rapidly colonizing root zones through metabolic versatility and the production of antagonistic compounds like antibiotics and lytic enzymes. These traits not only suppress soil-borne pathogens but also contribute to plant growth promotion. However, similar strategies are employed by plant growth-promoting bacteria (PGPB), which also colonize the rhizosphere and endophytic niches effectively. Therefore, when selecting *Trichoderma* strains for biocontrol, it is crucial to evaluate their interactions with beneficial microbes like PGPB to assess compatibility and avoid adverse effects on plant-associated microbial communities.
4. **Induction of Plant Defense System:** Plants defend themselves against pathogens through systemic acquired resistance (SAR), while certain microbes can trigger similar responses via induced systemic resistance (ISR). *Trichoderma*-induced systemic resistance (TISR) resembles rhizobacteria-induced ISR (RISR), both primarily mediated by jasmonic acid and ethylene

signaling pathways. Unlike SAR, RISR often lacks pathogenesis-related (PR) protein induction; however, some *Trichoderma* strains, like *T. hamatum* Th23, can upregulate PR genes (e.g., PR-1, PR-7) in response to pathogens like Tobacco Mosaic Virus. TISR also activates defense enzymes such as glucanases, chitinases, peroxidases, polyphenol oxidases, and antioxidant enzymes (e.g., CAT, SOD), reducing oxidative stress markers like H₂O₂ and MDA. Transcription factors such as NPR1 coordinate SAR and ISR pathways. Certain strains, such as *T. harzianum* TR274, induce defense genes (glu, chit, pal) in beans, and commercial products like BIOSPARK™ enhance insect resistance in other crops. TISR elicitors, including siderophores and antimicrobial compounds, vary by *Trichoderma* species—e.g., SM1 from *T. virens* induces defense, while in *T. harzianum* it may suppress it to promote colonization. Therefore, elicitor type and species specificity are key to understanding and applying TISR effectively.

Conclusion

Trichoderma offers promising potential for the effective control of various plant diseases due to its multifaceted antagonistic mechanisms, including mycoparasitism, antibiosis, and competition for nutrients and space. However, to fully harness its biocontrol capabilities, it is crucial to develop efficient and standardized methods for detecting and identifying *Trichoderma* antagonists, as well as evaluating their safety and efficacy across diverse agro-climatic conditions. Comprehensive risk assessments addressing its toxicity, ecotoxicity, and potential impacts on non-target organisms—both under in vitro and in field conditions—are essential prerequisites for responsible commercialization. Additionally, it is imperative to investigate the strain-specific interactions of *Trichoderma* with plants, soil microbiota, and pathogens to avoid unintended ecological disruptions. Further research is also needed to elucidate the molecular mechanisms underpinning *Trichoderma*-plant-pathogen interactions, enhance formulation technologies, and address societal and regulatory concerns associated with the release of novel microbial agents into the environment. Developing regulatory frameworks and public awareness programs will be vital to ensure the safe and sustainable adoption of *Trichoderma*-based biopesticides in modern agriculture.

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UNLOCKING GENETIC POTENTIAL OF CWRs AND UTILIZING PRE-BREEDING STRATEGIES FOR IMPROVEMENT OF *Brassica* spp.

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Abstract

Indian mustard (*Brassica juncea* (L.)) faces significant yield limitations due to biotic and abiotic stresses. Despite continuous breeding, productivity remains below potential, largely due to narrow genetic diversity in cultivated varieties. Crop wild relatives (CWRs) offer a vast, underexploited gene pool for novel traits like pest resistance and stress tolerance. However, direct CWR utilization is hindered by crossing barriers and undesirable linkage drag. Pre-breeding serves as a crucial tool to overcome these challenges, broadening the genetic base of Brassica species by introgressing beneficial traits from CWRs. This involves activities like germplasm characterization, creating new parent populations, and utilizing advanced techniques such as embryo rescue and somatic hybridization. Successful introgression of traits like *Sclerotinia* stem rot resistance from *Sinapis alba* and aphid tolerance from *B. tournefortii* highlights pre-breeding's importance. This strategy is essential for developing resilient, high-yielding mustard varieties adaptable to changing environmental conditions, ultimately enhancing food security.

Keywords: Pre-breeding, Crop Wild Relatives (CWRs). *Brassica juncea*, Stress Resistance

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is an economically important, edible oilseed crop of the *Brassicaceae* family belonging to the rapeseed-mustard (RM) group. *B. juncea* is cultivated in India, China, Bangladesh, Pakistan, Australia, Canada and some European countries. The *Brassicaceae* family has about 3709 species and 338 genera, displaying enormous diversity and being used as a source of oil, vegetables, mustard condiments, and fodder. The wild, natural counterparts of cultivated crops that are usually found in their original habitats are referred to as crop wild relatives (CWRs). India, ranking second globally in *Brassica* germplasm, has a significant collection. The National Bureau of Plant Genetic Resources (NBPGR) in India contributed 4095 indigenous and 3401 exotic rapeseed-mustard accessions from 1986–2006. The direct utilization of CWRs in breeding programs is often hindered by crossing barriers with cultivated species and the prevalence of undesirable alleles, potentially leading to linkage drag and the inheritance of unfavourable traits in subsequent generations. To overcome such issues pre-breeding serve as potential tool. Despite continuous breeding efforts over the past four decades, the national average productivity of Indian mustard (*B. juncea*) remains around 1400 Kg/ha, despite its actual yield potential reaching up to 3500-4000 kg/ha (Sinha *et al.*, 2020). Pre-breeding encompasses all activities that precede the stages of cultivar development, testing, and release. It aims to broaden the genetic base of cultivated Brassica species by incorporating traits from CWRs, which are known for their resilience to biotic and abiotic stresses. This is particularly important given the challenges

posed by climate change, evolving pest populations, and the need for improved agronomic traits such as yield and nutritional quality. Improving crop yield can also occur as a by-product of the introgression of genes conferring tolerance for biotic and abiotic stress, which may be neutral overall but sustain yield under specific stresses in the field.

Genetic Diversity in Brassica

There is enormous genetic diversity in Brassica species which is crucial for the development of resilient crops that can adapt to changing environmental conditions and resist diseases and insect pest. This diversity is primarily found within diploid species, such as *Brassica rapa* and *Brassica oleracea*, which exhibit higher genetic variation compared to polyploid species like *Brassica napus* and *Brassica juncea*. The genetic variation allows for the introgression of beneficial traits, which is essential for crop improvement efforts (Chaudhary *et al.* 2022).

The Role of Crop Wild Relatives

Crop wild relatives (CWRs) play a vital role in enhancing the genetic diversity of cultivated Brassica species. They serve as a source of novel genes that can confer desirable traits such as pest resistance, drought tolerance, and improved nutritional quality. The primary gene pool consists of closely related species like *Brassica oleracea*, while the secondary and tertiary gene pools include more distantly related species that can be utilized through advanced breeding techniques (El-Esawi, M. A., 2017). CWRs are essential for broadening the genetic base of crops, enabling breeders to overcome limitations imposed by the narrow genetic diversity found in cultivated varieties.

List of Potential CWRs in Brassica genus:

Sr. No	Biotic/Abiotic stress	Potential CWRs	Sr. No	Biotic/Abiotic stress	Potential CWRs
1	Alternaria blight	<i>Diplotaxis eruroides</i> <i>Sinapis alba</i> <i>Brassica fruticulosa</i> <i>Brassica tournefortii</i> <i>Camelina sativa</i> <i>Capsella bursa-pastoris</i>	4	Aphids	<i>Brassica fruticulosa</i> <i>Brassica montana</i> <i>Camelina sativa</i> <i>Crambe abyssinica</i> <i>Lepidium sativum</i>
2	Sclerotinia stem rot (SSR)	<i>Brassica fruticulosa</i> <i>Erucastrum cardaminoides</i> <i>Sinapis alba</i> <i>Capsella bursa-pastoris</i>	5	Drought stress	<i>Sinapis alba</i> <i>Brassica fruticulose</i> <i>Brassica tournefortii</i> <i>Camelina sativa</i> <i>Capsella bursa-pastoris</i> <i>Crambe abyssinica</i>
3	White rust	<i>Diplotaxis eruroides</i> Interspecific cross from <i>B. tournefortii</i> , <i>B. napus</i> and <i>B. carinata</i> . <i>Brassica fruticulose</i> <i>Brassica tournefortii</i> <i>Camelina sativa</i> <i>Lepidium sativum</i>	6	Heat stress	<i>Sinapis alba</i> <i>Brassica tournefortii</i> <i>Lepidium sativum</i>

Utilization of CRWs for improving traits in *Brassica*

Despite having number of CRWs for various traits in *Brassica* genus, their transfer into cultivated forms is hindered by many reasons. The effective utilization of these CRWs is very important and they can serve as potential donors for various stresses according to changing environmental conditions. Approaches like hybridization, Backcross breeding and genomics tools like Marker Assisted Selection (MAS) can be useful for transferring traits but Pre-breeding serve as potential approach among these.

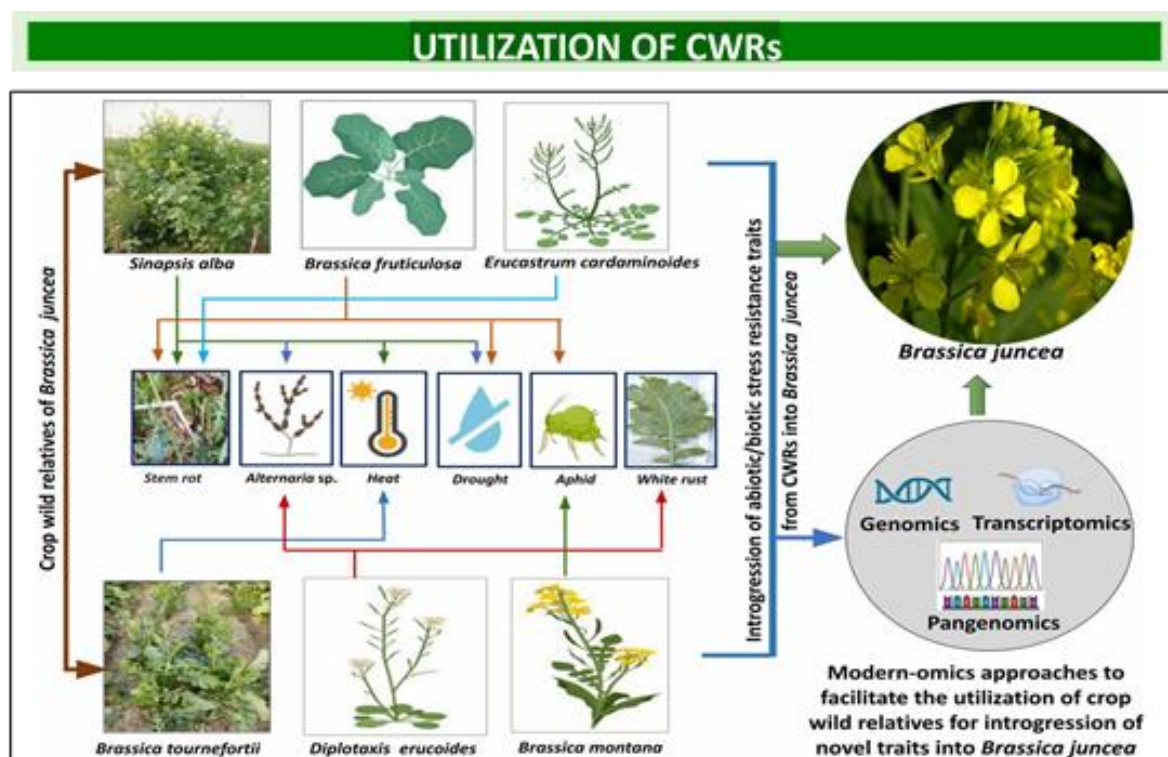


Fig. 1: Utilization of CWRs for improvement of Indian Mustard.

Adapted from: Verma et al. 2023

Pre-Breeding Activities

1. Characterization of germplasm
2. Creation of new parent populations
3. Introgression of new traits from other useful sources, exotic germplasm or a landrace or related species
4. Creation of novel traits, for instance, through mutation breeding followed by backcrosses to good parents
5. Creation of polyploids
6. Acquisition of new information on crop genetics
7. Plant tissue culture

All these activities leads to introgression of desirable traits into cultivated spp, and also broaden the genetic base of crop plants. Still various challenges or problems need to face during the process of pre-breeding. Various challenges and there solutions are proposed in the fig. 2.

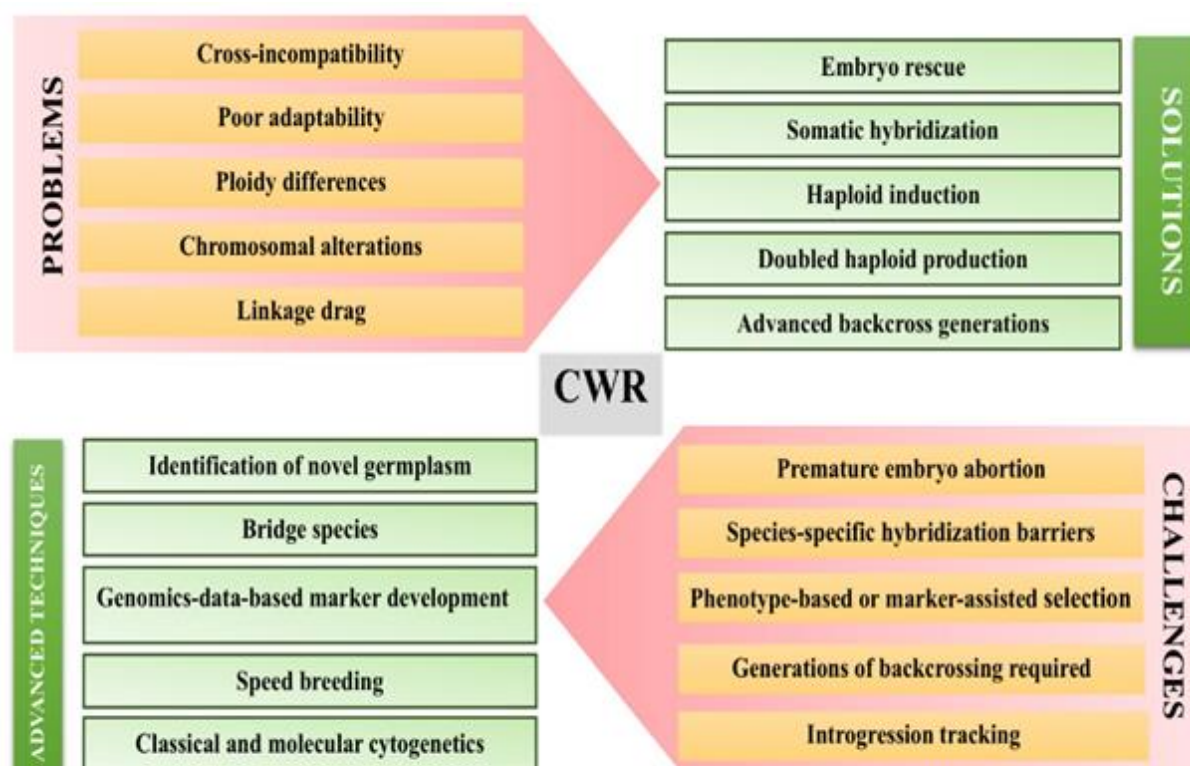


Fig. 2: Problems and potential strategies for utilization of CWR for crop improvement.
 Adapted from: Kashyap *et al.*, 2022

Milestones of Pre-Breeding in *Brassica* spp

- Traits like low erucic acid content from *B. rapa* and low glucosinolate, increased oleic acid levels and white rust resistance from *B. napus* has been introgressed to *B. juncea*.
- Higher yield and short duration trait introgressed from *B. rapa* to *B. napus*.
- Genes responsible for various biotic stresses have been introgressed into cultivated spp. like, resistance to beet cyst nematode from *Raphanus spp.*, resistance to Alternaria leaf spot from *D. eruroides*, and resistance to black leg from *B. tournefortii* and *Sinapis arvensis* have been introgressed.
- An improved CMS system of *B. juncea* having cytoplasm of the wild species *D. berthautii* was developed by Bhat *et al.* (2008) and from *B. fruticulosa* (Atri *et al.*, 2016).
- Resistance against *Sclerotinia* stem rot (SSR) from *S. alba* (Kumari *et al.*, 2020) and *B. fruticulosa* to *B. juncea* (Rana *et al.*, 2017).
- Tolerance against aphids was transferred from *B. tournefortii* (Kumar *et al.*, 2001).
- Recently, super high erucic acid content *B. carinata* (2n = BBCC, Allotetraploid) was also produced by interspecific hybridization with *B. rapa* (2n = AA) and *B. juncea* (2n = AABB) (Roslinsky *et al.*, 2021).

Conclusion

The effective utilization of wild germplasm in Brassica breeding is hindered by insufficient characterization of traits and fragmented information, necessitating systematic investigations. While modern breeding techniques are advancing with accessible sequencing tools, understanding

allelic variation in exotic germplasm is essential for progress. Although there have been successful crosses between cultivated Brassica species and their wild relatives, published data on the introgression of beneficial nuclear genes remains limited. To improve the success rate of inter-specific hybrids, particularly between *Brassica juncea* and crop wild relatives (CWRs), standardization of protocols is crucial. Despite extensive breeding efforts over the past four decades, the average productivity of Indian mustard remains limited. The genetic relationship between Brassica and *Arabidopsis thaliana* offers opportunities to identify candidate genes for important traits. In India, pre-breeding efforts have led to the identification of over twenty-five white rust resistance donors among *B. juncea* germplasm, which are now integral to breeding programs aimed at enhancing resistance to this disease.

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WATER EVALUATION AND PLANNING (WEAP) MODEL : A SMART APPROACH TO WATER MANAGEMENT

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Abstract

The Water Evaluation and Planning (WEAP) model is a comprehensive, integrated decision-support tool designed to facilitate sustainable water resource management. Developed by the Stockholm Environment Institute, WEAP offers a robust framework for simulating water systems, balancing supply and demand, and assessing the impacts of various development, policy, and climate scenarios. It incorporates water sources, users, infrastructure, and environmental requirements within a user-friendly, scenario-based platform. WEAP enables policymakers, planners, and researchers to evaluate current conditions and explore future possibilities using scientifically grounded methods. With applications across urban planning, agriculture, watershed management, and climate adaptation, WEAP has become a vital instrument for water governance worldwide. This article explores the conceptual framework, key components, benefits, limitations, and real-world applications of the WEAP model.

Keywords: WEAP Model, water supply and demand, climate

Introduction

Water is an important resource for human development. Water is used as an input for successful agriculture, industries and growth of urbanization. Along with ground water, surface water reservoirs are satisfying the requirement of drinking water, irrigation and industrial sector. Water is one of the most valuable natural resources we have, yet it's often under stress due to overuse, climate change, and poor planning. Managing water in a sustainable, efficient, and equitable way is a growing global challenge. The Water Evaluation and Planning (WEAP) model serves as a vital, modern, and science-based tool that enables us to manage our water resources efficiently and sustainably.

What is WEAP?

WEAP is a general multi-purpose, multi-reservoir simulation program which determines the optimal allocation of water for each time-step according to demand priorities and supply preference.

The Water Evaluation and Planning (WEAP) model is a computer-based software tool and it is developed for comprehensive and integrated water resources planning. Developed by the Stockholm Environment Institute (SEI), it provides a comprehensive, user-friendly framework for simulating water supply and demand systems under current and future scenarios.

It allows policymakers, researchers, and engineers to:

- Assess current water usage
- Analyze future demand and availability

- Explore different development, climate, and management scenarios
- Plan for sustainable water use

How Does WEAP Work?

WEAP uses a “what-if” scenario-based approach. Users build a model of their water system, input data such as river flows, water demands, population, and infrastructure, and then simulate how water is allocated under different policies or environmental conditions.

It operates on the principle of water balance accounting, considering:

- Inflows (rain, river flow, imports)
- Outflows (evaporation, usage, exports)
- Storage (reservoirs, aquifers)
- Demands (agriculture, domestic, industry, ecology)

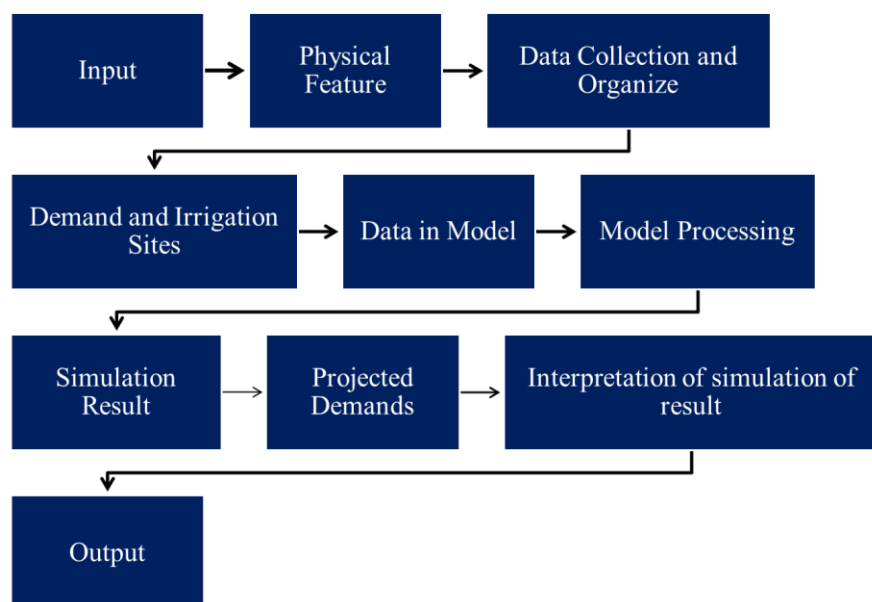


Fig. Flow Chart of WEAP Model Processing

Key Features of WEAP

1. **Graphical Interface** : Allows drag-and-drop system building with nodes and links.
2. **Scenario Analysis** : Create and compare multiple future scenarios (e.g., population growth, irrigation expansion, climate change).
3. **Demand Sites** : Simulate water consumption by urban, rural, industrial, and agricultural users
4. **Hydrology & Groundwater** : Incorporates rainfall-runoff and groundwater simulation models.
5. **Water Quality & Ecosystems** : Evaluates impacts on water quality and environmental flows.
6. **Linking with Other Models** : Can connect with MODFLOW (groundwater) and LEAP (energy).

Applications of WEAP

- Integrated River Basin Management (e.g., Ganga, Nile, Zambezi)
- Urban Water Supply Planning
- Agricultural Water Management
- Climate Change Impact Studies

- Environmental Flow Assessments
- Transboundary Water Negotiations

Scenario Examples

Here are some questions WEAP can help answer:

- What happens if rainfall decreases by 15% over the next 20 years?
- How would water demands change if a city's population doubles?
- What will be the effect of building a new reservoir upstream?
- How does shifting to drip irrigation impact overall water demand?

Benefits of Using WEAP

Advantage	Description
Integrated Analysis	Considers supply, demand, quality, policy, and ecosystem needs together
User-Friendly	Visual model building and simple data entry
Scenario Planning	Evaluate trade-offs between different policy options
Widely Used	Applied in 100+ countries and endorsed by global institutions
Science-Based	Built on sound hydrological and system analysis principles

Limitations of WEAP

- Requires **accurate and sufficient data** for effective simulation
- May need **technical expertise** to set up complex systems
- Not suitable for **detailed flood modelling** or **real-time operation planning**

Who Uses WEAP?

- National and local **water planning agencies**
- **Research institutions** and universities
- **NGOs** working in water and environmental management
- **International development agencies**
- **Hydrologists and engineers** for project assessment

Conclusion

The WEAP model offers a structured and intuitive way to understand, evaluate, and plan water systems. In a time where every drop counts, this model supports decision-makers in crafting sustainable, equitable, and resilient water management solutions. Whether you are managing a city's water supply or planning irrigation for a river basin, WEAP gives you the power to make informed, data-driven decisions.

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RICE STRAW MANAGEMENT – WASTE TO WEALTH IN AGRICULTURE

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Abstract

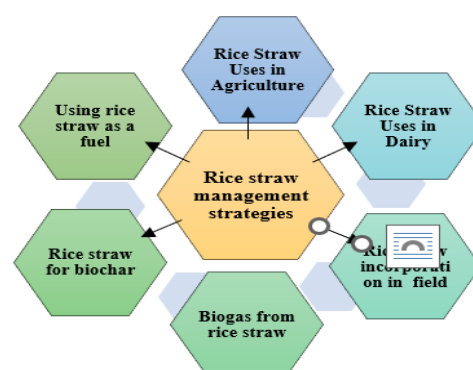
A significant by-product of the world's rice production, rice straw is frequently burned in the open, which has detrimental effects on the environment and human health. Nonetheless, this trash can be transformed into useful resources through sustainable management techniques. Composting for soil enrichment, growing mushrooms, producing charcoal, producing biogas, and producing industrial fuel are some of the uses. According to research, rice straw includes useful substances that can be extracted to produce ethanol and other industrial resources, such as cellulose, hemicellulose, and lignin. While combustion techniques such as fluidized bed burners and grate-fired burners convert straw into energy with little emissions, field integration and composting improve soil health.

Keywords: Rice straw, Rice straw management, Sustainable agriculture, Waste, Wealth

Introduction

Along with the huge production of rice all over the world, a significant amount of rice straw is produced as its by-product and its inappropriate disposal, particularly by open burning presents serious hazards to both the environment as well as human health. After sugarcane bagasse and maize straw, rice straw is the third-largest agricultural residue worldwide. In India Millions of tons of straw are burnt annually, contributing to the haze in cities like Delhi and many more (Gupta *et al.*, 2004). In the era of global warming and pollution, burning of rice stubbles worsen the situation more. The idea of managing rice straws sustainably has emerged with certain studies and research works. Most of the farmers globally have an easy access to rice straw which is a true organic component and natural residue of rice crop (Dobermann & Fairhurst 2002). If correctly handled, rice straw turns into a useful resource that supports environment friendly practices and sustainable agriculture. Addition of straw increases soil fertility and reduces the chemical fertilizer requirement. Pyrolyzation of rice straw to produce biochar reduced the carbon emission and its application enhanced crop yield (Zhou *et al.*, 2018).

Illustration of rice straw management strategies through flowchart



Rice Straw Uses in Agriculture:**Paddy straw for mushroom production :**

In 1943, Thomas and his colleague's cultivated mushrooms for the first time in Coimbatore India by using paddy straw. Growing mushrooms on rice straw is highly sustainable and environment friendly. The cellulose, hemicellulose, and lignin found in rice straw are broken down by the enzymes in the mushroom and used as fuel for mycelial development. The fibrous texture of rice straw creates a suitable environment for the mushroom's growth by allowing air to circulate and efficiently retaining moisture. When utilized in beds or stacks, rice straw naturally supports the warm, humid conditions (30–38°C) that paddy straw mushrooms prefer. Studies have shown that it takes Only 15 days to produce paddy straw mushrooms (Kaushik *et al.* 2018) (Fig.1).

Using Rice Straw as Soil Nutrients :

Rice straw is rich in calories and nutrients (Yoshiro & Duoug 2015). Microbial populations break down organic waste during the composting process (Tang *et al.* 2007). Numerous benefits of composting include reduced volume and mass, a high carbon to nitrogen ratio, and hygienic conditions. The composting process meets the requirements to be used as fertilizer since it transforms unstable ammonia into stable organic material, may eliminate pathogens, and reduces trash. Rice straw is resistant to microbial activity due to its high C/N ratio. Therefore, rice straw is composted along with other organic waste for better outcomes. The resulting compost aids in plant growth and is stable enough for use in agriculture field (Fig. 2).



Fig. 1 - Rice straw mushrooms

Rice Straw Uses in Dairy

Utilizing rice leftovers as livestock feed : The dried stalk left after rice harvesting can be utilized as roughage for ruminants as rice straw has low digestibility and protein content. It can be made more nutritious by treating it with urea or adding feeds high in protein.

Utilizing rice leftovers as livestock bedding : Punjab Agricultural University, Ludhiana advised farmers to utilize rice straw for livestock bedding during winter to provide a dry, clean, pleasant, non-slip, and hygienic environment. It will reduce the injury and lameness. Animals with healthy legs produce more milk and reproduce more effectively (Kumar *et al.* 2015, Kargbo *et al.* 2010, Singh *et al.* 1995). It reduces environmental pollution, promotes animal welfare and transforms an agricultural waste into a useful on-farm resource. Encouragement of this practice among farmers can have a major impact on rural resilience and sustainable agriculture (Fig. 3).



Fig. 2 - Rice straw compost

Rice Straw Incorporation in Field

Degradation of the soil results from burning crop debris (Yadav *et al.* 2015). Incorporate rice straw to the soil instead of burning is a smart and environmentally responsible move. It supports sustainable agricultural practices, lowers pollution, and creates healthier soils. Incorporating straw can be crucial to attaining climate-smart and sustainable agriculture if the right resources and knowledge are available (Fig. 4).

Biogas from Rice Straw

In cement-brick underground containers, rice straw and cow manure are alternately heaped to produce biogas. In order to initiate fermentation, the tank is filled with water; after a week, gas is produced. A tonne of straw produces 5–6 cubic meters of biogas over a period of four months. Slurry residue is turned into organic fertilizer (Fig. 5).



Fig. 3 - Cattle bedding made from rice straw



Fig. 4 - Incorporation of rice straw in the field

Rice Straw for Biochar

Thermochemical pyrolysis of rice straw (biomass) produces biochar, a form of charcoal that is produced biologically. The thermochemical breakdown of organic compounds at a high temperature without oxygen is known as pyrolysis. Larger molecules decompose into smaller ones during the pyrolysis process. Biochar raises the pH level in an acidic environment even though it can never naturally give nutrients to soil. Therefore, using biochar may help reduce greenhouse gas emissions, boost crop yields, and improve soil fertility (Yoshiro & Duoug 2015) (Fig. 6).



Fig. 5 - Biogas produced from rice straw

Using Rice Straw as a Fuel

Rice straw is a useful industrial raw material as well as feed, fuel, and fertilizer. Fluidized bed burners and grate-fired burners are examples of combustion systems. Grate-firing is an economical method that works with straw that has up to 65% moisture content. Higher combustion efficiency and reduced NO₂ emissions are two benefits of fluidized bed combustors. However, it is expensive to carry wet straw, and straw that has more than 25% moisture content may ferment (Zhiqiang *et al.*, 2011). Energy content, ash composition, moisture content & volatility are important aspects when designed a largescale rice straw combustion system. Roads, cement, bricks, and embankments may all be made from valuable by-products like fly ash and bottom ash (Verma, 2014).



Fig. 6 - Biochar made from rice straw

Conclusion

Once thought of as an agricultural waste, rice straw has enormous promise as a resource for agriculture's sustainable development. Waste can be turned into wealth by utilizing creative techniques such as composting, biochar, biogas production, mushroom culture and industrial use. Good management promotes climate-resilient farming enhances soil health and creates rural income in addition to lowering environmental pollution from residue burning. Adopting solutions for different rice straw management is essential to create an agricultural system as a sustainable, environment friendly and profitable.

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VIRTUAL REALITY IN AGRICULTURE AND DAIRY: A NEW DIMENSION OF FARMING

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Abstract

Virtual Reality (VR) is an immersive technology, that is transforming the way we perceive and engage in agriculture system. VR is classified into 3 types based on the extent of immersion into non-immersive, semi-immersive and immersive. Today, there is huge scope for using VR in agriculture and dairy, starting from farm planning, training and skill development to virtual tours, which engages farmers in an immersive world for practical understanding. Even though there are several advantages related to use of VR like enhanced learning, better planning and decision making, there are some limitations like limited awareness, high initial investment and digital literacy levels which is hindering its full adoption among farming communities. By addressing these limitations, its utility and adoption can be fostered among farmers leading to sustainable development by linking virtual world with real-world practices.

Key words: Digital literacy, Immersive, Technology, Virtual etc

Introduction

As technology continues to reshape every aspect of our lives, agriculture is rapidly embracing its transformative power. Virtual Reality (VR) is one such technology, which is a computer-generated simulation that creates immersive environments, offering both visual and auditory experiences to users (Zhou & Calvo, 2018). Whether simulating crop and dairy scenarios or training future farming professionals, VR is redefining how we perceive and engage with agricultural systems. Typically, VR utilizes headsets equipped with stereoscopic displays, spatial audio, and motion-tracking sensors to fully replicate a virtual setting (Jerome & Greenberg, 2021). VR allow users to immerse themselves in a 3D environment where they can interact with virtual objects and explore the surroundings (Jensen, 2017). As agriculture moves toward greater precision and innovation, VR stands at the cutting edge, revolutionizing how we cultivate, educate, and prepare for the farms of tomorrow.

Types of Virtual Reality (VR)

Virtual Reality is classified into 3 types based on the level of immersion. They are non-immersive, semi-immersive, and fully immersive (Musa *et al.*, 2022).

1. Non-Immersive VR: This is the most basic form of VR, experienced through a regular screen like a computer or mobile. Users interact with the virtual environment using a keyboard, mouse, or touch controls. Common in farming simulations.

2. Semi-Immersive VR: Offers a partially immersive experience using large screens or projectors with 3D visuals. Users feel somewhat inside the environment but can still see the real world. commonly used in Agri-training centres for interactive demonstrations.

3. Fully Immersive VR: Provides a complete, realistic virtual experience through headsets and motion tracking. Users feel completely immersed in a virtual environment. Used for high-level trainings like operating any big equipments or managing virtual livestock.

Applications of VR in agriculture and dairy

1. **Training and skill development:** Farmers can be trained in a simulated environment. It helps in learning machinery operation, safety procedures, and animal handling without real-world risks. Adopting VR technology alongside training can enhance technical skills and improve knowledge management, helping maintain quality over time (Carruth *et al.*, 2020).
2. **To understand Soil profile:** Soil when viewed through VR sets, can display layered soil structures with different characteristics. This visualization improves understanding of soil health, drainage, and nutrient needs.
3. **Pests and Disease identification:** Simulated pest and disease symptoms can be displayed interactively. By getting exposed to these symptoms virtually, farmers can easily recognize and plan for its management in early stages of live outbreaks.
4. **Virtual tours:** With the help of VR headsets farmers can take guided VR tours of model farms, dairy units or agricultural institutions. This exposure helps in better planning, knowledge gain and adoption of best practices.
5. **Farm planning and management:** VR helps simulates irrigation plans, layout of dairy farms including cattle sheds, feeding zones, and waste management systems. It allows farmers to visualize and optimize space in his farm before actual construction or modification.
6. **Livestock management:** VR simulations train users in animal health checks, milking procedures, and shelter design. It also assists in learning early signs of disease or distress in livestock.

Advantages of Virtual Reality

1. **Enhanced Learning and Training:** Provides immersive, risk-free environments for training in machinery use, animal care, and farm practices.
2. **Better Planning and Visualization:** Allows 3D modeling of farms and dairy setups to test layouts, infrastructure, and workflows before implementation.
3. **Early Problem Identification:** Helps in identifying pests, diseases, and soil issues through simulated scenarios, improving response time.
4. **Remote Access and Demonstration:** Enables virtual tours and demonstrations of successful farming practices, making extension education more accessible.
5. **Cost-Effective Prototyping:** Reduces trial-and-error costs by testing ideas in a virtual setup before making real investments.
6. **Improved Decision-Making:** Data visualization in VR supports informed decisions related to resource allocation, animal health, and crop planning

Limitations of Virtual Reality

1. **Low awareness:** Awareness about VR's benefits in agriculture is still low, slowing its adoption among stakeholders.
2. **High initial cost:** VR equipment and software development are expensive, making it less accessible for small or marginal farmers.
3. **Lack of technical skills:** Many farmers may lack the digital literacy required to operate VR tools effectively.

4. **Proper infrastructure requirement:** Requires stable electricity, high-speed internet, and compatible devices, which are often lacking in rural areas.
5. **Regular maintenance and upgradation:** VR systems need regular maintenance and software updates, which may be costly and technically demanding.
6. **Data Privacy and Security concerns:** Usage of VR tools with embedded data systems may raise concerns over privacy and misuse of farm data.

Summary

Virtual Reality is a technology that provides immersive and interactive experiences. In the field of agriculture, it assists with farm planning, soil profiling, and pest identification by utilizing 3D simulations. In the dairy sector, VR supports livestock management, health monitoring, and facility design. It provides hands-on training for farmers in a risk-free virtual environment. VR enables virtual farm tours and demonstrations, making knowledge more accessible. It enhances decision-making by simulating various real-world scenarios. But long-term usage may lead to VR sickness, cognitive overload, or detachment. Limitations include high cost, limited infrastructure, and low awareness among farmers. Despite these challenges, VR is having great potential to modernize and revolutionize agriculture and dairy practices.

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WOMEN-LED EXTENSION MODELS FROM KITCHEN TO KRISHI

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Abstract

India's agriculture-driven economy heavily relies on women, who contribute over 70% of farm labour across various activities, including land preparation, livestock care, and post-harvest work. However, in many patrilocal societies, they lack decision-making power and equal access to resources and training, limiting their full potential. FAO (2011–12) estimates that equal access could raise yields by 20–30%, increase output by 2.5–4%, and cut global hunger by 12–17%. Thus, empowering women in agriculture is essential for both equity and sustainable rural development.

Keywords: Women, Agriculture, Production, Empowerment

Introduction

Women form the backbone of the agricultural workforce and play a vital role in India's economy. When women have access to land, leadership roles, resources, and opportunities, it leads to stronger economic growth, improved food security, and better prospects for both present and future generations. Agriculture in India is largely a family-based activity, and women contribute significantly across various sectors including crop production, food security, dairy, nutrition, sericulture, and fisheries. In all developing regions, women are deeply involved in agriculture and rural economic activities. Their roles, however, vary widely across regions and are rapidly evolving due to changing economic and social dynamics in the agricultural sector. The rise of contract farming and modern supply chains for high-value crops presents both new opportunities and challenges for women. These outcomes are shaped by the unique roles, responsibilities, and constraints that women face in agriculture.

Women in Agriculture

Women play diverse roles in agriculture—as independent farmers, unpaid family workers, and as paid or unpaid laborers on other farms and in rural enterprises. They are actively involved in both crop and livestock production, contributing at both subsistence and commercial levels. Women manage a wide range of agricultural activities, including crop cultivation, animal husbandry, and fish farming. According to FAO (2010), they form a significant part of the agricultural labor force. In South Asia, India dominates the regional average, with women consistently comprising just over 30% of the agricultural workforce. In contrast, other countries like Pakistan and Bangladesh have seen notable increases in female participation in agriculture. In Pakistan, women's share in agriculture has nearly tripled since 1980, reaching around 30%, while in Bangladesh, women now represent over 50% of the agricultural labor force.

Domains of empowerment

Five domains of empowerment (5DE): This sub-index assesses whether women are empowered across the five domains examined in the WEAI.

- **Production:** Involvement in individual or joint decision-making regarding food and cash crop cultivation, livestock rearing, and fisheries, along with the level of autonomy in agricultural production.

- **Resources:** Ownership of, access to, and decision-making authority over key productive assets, including land, livestock, farming tools, consumer goods, and financial credit.
- **Income:** Control, whether sole or shared, over income generation and household expenditures.
- **Leadership:** Participation in social or economic groups and the confidence to speak in public settings.
- **Time:** Distribution of time between productive work and domestic responsibilities, along with personal satisfaction regarding the time available for rest and leisure.

Fig: 1 Five domains of empowerment in the WEAI

Domain	Indicators	Weight
Production	Input in productive decisions	1/10
	Autonomy in production	1/10
Resources	Ownership of assets	1/15
	Purchase, sale, or transfer of assets	1/15
	Access to and decisions on credit	1/15
Income	Control over use of income	1/5
Leadership	Group member	1/10
	Speaking in public	1/10
Time	Workload	1/10
	Leisure	1/10

Reference: <https://www.renature.co/articles/empowering-women-in-agriculture/>

Women-Led Extension Models

Women-led extension models emphasize empowering rural women by involving them directly in agricultural knowledge dissemination, skill development, and decision-making processes. These models aim to bridge the gender gap in agricultural extension by ensuring that women are not just recipients but also active providers of agricultural advisory services.

Women led Extension models

- 1) **Farm Women Groups (Self-Help Groups/SHGs)** : Mobilize rural women into SHGs for collective learning, credit access, and entrepreneurship. Enable training in agriculture, livestock, nutrition, and value addition. Example: **Mahila Kisan Sashaktikaran Pariyojana (MKSP)** under NRLM.
- 2) **Women Farmer Field Schools (WFFS)** : Facilitate experiential learning through season-long training. Focus on sustainable practices, pest management, and climate resilience. Promote leadership and group-based problem solving.
- 3) **Krishi Sakhi Model** : Women selected from the community and trained as **para-extension workers**. Provide doorstep extension services and mobilize women farmers. Common in states like Maharashtra under NRLM and State Rural Livelihood Missions.
- 4) **Community Resource Persons (CRPs)** : Women trained as CRPs in various thematic areas like organic farming, nutrition gardens, or livestock management. Serve as peer educators, ensuring culturally appropriate communication.

- 5) **Women Agri-Entrepreneurs** : Promote women as agri-input dealers, custom hiring center operators, or service providers. Blend extension with enterprise for financial empowerment. Supported by NGOs and agri-tech startups.
- 6) **ICT-Based Women Extension Agents** : Women are trained to use mobile apps, helplines, and video-based learning tools. Help disseminate weather forecasts, market prices, and farm advisories to other women farmers.

Constraints and Opportunities:

Rural women face several constraints that limit their agricultural productivity and profitability. These include limited control over resources due to legal and cultural norms, restrictive property and inheritance laws, and the burden of balancing household responsibilities with market production. Additionally, ecological challenges and poorly designed agricultural services, often not tailored to women's needs, further hinder their progress. Addressing these issues through gender-sensitive extension strategies can unlock significant opportunities for rural women's empowerment and agricultural development.

Conclusion

Women-led extension models exemplify a powerful shift from traditional domestic roles to active leadership in agriculture and rural development. By recognizing and strengthening women's roles as farmers, facilitators, and knowledge sharers, these models promote inclusive, sustainable, and community-driven growth. Empowering women "from kitchen to krishi" not only enhances agricultural outcomes but also uplifts entire rural communities through increased resilience, equity, and self-reliance.

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ROOFTOP FARMING: A SCIENTIFIC APPROACH TO URBAN AGRICULTURE

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Introduction

With increasing urbanization, declining per capita agricultural land, and growing concerns over food security, terrace farming is also known as rooftop farming, has gained significant attention. It involves cultivating vegetables, fruits, and medicinal plants on the roofs of buildings, and integrates concepts from urban horticulture, agroecology, and sustainable waste management. Globally and in India, urban agriculture is being recognized not only for its role in food production but also for its ecological and social contributions to resilient cities (Appolloni and Gianguinto, 2022).

Terrace farming is built on scientific and ecological principles that optimize vertical space, utilize organic waste for soil nutrition, and conserve water through efficient irrigation techniques. This article explores the technical, environmental, and socio-economic aspects of terrace farming with practical examples and policy implications.

Scientific foundations of terrace farming

1. Structural and engineering considerations

Before initiating a terrace farm, the structural integrity of the roof must be assessed:

- **Load-bearing capacity:** Rooftops should support at least 150–300 kg/m². Consultation with civil engineers ensures long-term safety.
- **Waterproofing:** Use of waterproof membranes (e.g., EPDM sheets, bituminous layers) prevents seepage.
- **Drainage systems:** Sloped roofs with outlets and drain tiles reduce water stagnation and root diseases.

2. Growing medium: engineered soils for light weight and nutrient efficiency

- **Soil-based medium:** A common mix includes 30% garden soil, 30% organic compost, 30% cocopeat, and 10% sand or perlite. Cocopeat increases aeration and water retention.
- **Soilless medium:** Used in hydroponics, includes expanded clay, perlite, vermiculite, or nutrient-enriched cocopeat.
- **Scientific monitoring includes:**
 - a) pH (6.0–7.5) and Electrical Conductivity (EC) for nutrient availability.
 - b) Periodic analysis of macro (NPK) and micro-nutrient status.

3. Cultivation techniques

- **Containers:** Grow bags, recycled drums, earthen pots, and raised beds are used based on crop type and root depth.
- **Vertical gardens:** Use of walls, racks, or stacked containers to grow leafy greens and herbs.
- **Trellis systems:** For creepers like gourds, tomatoes, and cucumbers.

4. Crops suitable for terrace farming

Crop Type	Examples	Notes
Leafy Greens	Spinach, Methi, Lettuce	Quick-growing; can be harvested multiple times
Root Vegetables	Carrots, Radish, Beetroot	Require 8–10 inches depth
Fruiting Crops	Tomato, Brinjal, Chillies	Need staking and deeper beds
Creepers	Cucumber, Bitter gourd, Beans	Vertical space-saving
Herbs	Mint, Coriander, Basil	Require less space and quick harvesting

5. Water and Nutrient Management

A) Irrigation methods

- **Drip irrigation:** Reduces water use by up to 60%, especially suitable for summer months.
- **Wick irrigation:** Capillary action helps small pots remain hydrated with minimal water.
- **Rainwater harvesting:** Rooftop catchments linked to storage tanks with filters.

B) Organic nutrient sources

- **Vermicompost and compost:** Made from kitchen waste; rich in humus and microbial life.
- **Liquid fertilizers:**
 - **Jeevamrutha:** Fermented cow dung-based tonic.
 - **Panchagavya:** Blend of cow products with jaggery and banana.
 - **Compost tea:** A microbial-rich liquid extracted from mature compost.
- **Foliar sprays:** Seaweed extract, micronutrient solutions, and fermented bioenzymes.

6. Pest and Disease Management

Terrace farming benefits from a closed ecosystem and minimal external pest influx, yet proactive management is essential:

- **Botanical pesticides:** Neem oil (2–5 ml/L), garlic-ginger-chilli decoctions.
- **Biological agents:** *Trichoderma*, *Pseudomonas fluorescens* for fungal and bacterial disease control.
- **Physical methods:** Yellow sticky traps, insect-proof nets, hand-picking of caterpillars.

Integrated Pest Management (IPM) is preferred over chemical methods due to proximity to living spaces.

Benefits of terrace farming

a. Environmental impact

- **Temperature reduction:** Rooftop vegetation reduces surrounding temperatures by 5–7°C, mitigating the Urban Heat Island effect.
- **Carbon footprint reduction:** Local food production cuts down transportation emissions.

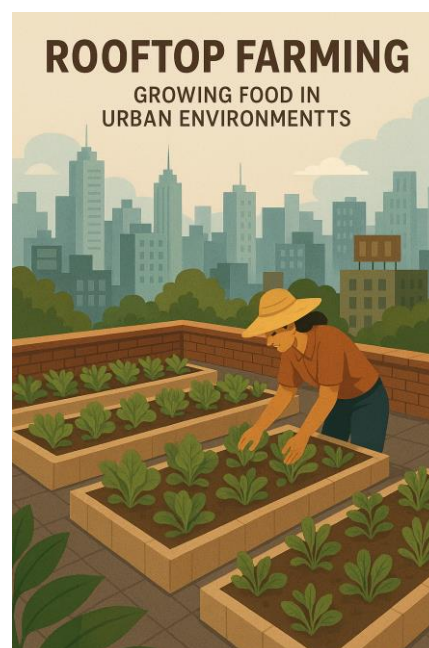


Figure 1: Terrace farming or rooftop farming

- **Organic waste recycling:** Terrace gardens convert 1–2 kg of daily kitchen waste into nutrient-rich compost.

b. Health and wellbeing

- Fresh pesticide-free produce improves dietary diversity and reduces chronic disease risks.
- Gardening promotes physical activity and mental health.
- Enhances biodiversity by attracting pollinators, birds, and beneficial insects.

c. Women and youth empowerment

- Terrace gardening programs in urban India have seen high participation of homemakers and students.
- Skill development in composting, propagation, and design fosters entrepreneurship.

Government Initiatives and Policy Support

- **Urban Greening Missions:** Smart Cities Mission and AMRUT include rooftop gardening components.
- **Municipal Subsidies:** States like Tamil Nadu and Delhi provide financial support for compost bins and grow bags.
- **ICAR & KVKS:** Training programs, field demonstrations, and start-up incubation.
- **Startups:** Private companies offer turnkey solutions with maintenance services and app-based monitoring.

Constraints and future outlook

Challenges

- Initial setup cost and maintenance effort.
- Lack of standardized guidelines on nutrient management and waste recycling.
- Limited awareness in non-metropolitan areas.

Way Forward

- Integration of terrace farming into school and college curricula.
- Public-private partnerships to scale up urban agriculture.
- Scientific validation of traditional practices and localized innovation.

Conclusion

Terrace farming presents a practical and scientifically grounded approach to achieving food security, climate resilience, and environmental sustainability in urban spaces. As cities continue to expand, integrating rooftop agriculture into urban planning will be key to creating liveable, green, and self-reliant communities.

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GROWING BEYOND SOIL: THE FUTURE OF FARMING WITH HYDROPONICS AND AEROPONICS

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Introduction

As the global population increases, the need for sustainable, space-efficient, and resource-smart agriculture has never been more urgent. Traditional soil-based farming is under increasing pressure from climate change, urbanization, and land degradation. Soilless farming is an innovative method of growing plants without using natural soil. This technique includes systems like hydroponics, aeroponics, and aquaponics, offering a controlled environment for efficient plant growth. Hydroponics uses just 10 per cent of the water compared to soil agriculture, reducing field water use (AlShrouf, 2017). Aeroponics goes further, consuming only 20 litres per plant cycle of tomatoes versus 70 litres in hydroponics and in traditional soil cultivation, it requires upto-400 litres of water to grow one kg of tomatoes (Zhang *et al.*, 2018). These tech efficiencies are valuable in addressing challenges such as climate-induced droughts, limited natural resources, and rapid urbanization.

What is Soilless Farming?

Soilless farming is defined as cultivating crops without soil, using alternative methods to deliver water, nutrients, and oxygen directly to the plant roots. Two such techniques are

Hydroponics: Plants are grown in nutrient-rich water solutions, often supported by inert media like perlite or coco peat.

Aeroponics: Plants are suspended in air, and their roots are sprayed with nutrient solutions at regular intervals. These systems can be set up indoors, in greenhouses, or in vertical farms, making them ideal for urban and climate-affected regions.

Why soilless farming?

With the continuous decline in cultivable agricultural land- largely due to its conversion into commercial spaces, erosion of fertile soils, unpredictable climate patterns & monsoons, and the depletion of natural resources- soilless farming systems offer a timely and sustainable alternative. Soilless farming, particularly hydroponics and aeroponics, emerges as a revolutionary solution that redefines how we grow food without soil & real climate, with less water, and in minimal space for robustly increasing population pressure. soilless farming presents a sustainable solution to meet the rising demand for safe and nutritious food.

Advantages of Soilless Farming

Resource use efficiency: With freshwater scarcity and diminishing arable land, soilless farming systems are no longer experimental- they are necessary. Hydroponic systems use approximately 10 per cent of the water required for conventional farming, while aeroponics can cut water usage by up to 98 per cent (AlShrouf, 2017; Pomoni *et al.*, 2023). These methods also support high-density

planting, especially in vertical systems, optimizing both land and water resources. As a result, they deliver significantly greater yields per square foot compared to traditional agriculture.

Sustainability: Soilless cultivation has gained prominence as a modern farming technique due to its simplicity and clean cultivation (Sharma *et al.*, 2018). It promotes efficient water use and supports self-sustaining agricultural practices. When comparing traditional soil-based farming to soilless systems, greenhouse gas emissions are notably lower-0.23 kg CO₂ equivalent for soil cultivation versus 0.11 kg CO₂ equivalent for soilless methods (Martinez-Mate *et al.*, 2018). Additionally, aeroponic systems operated under controlled environments can cut fertilizer use by up to 60 per cent and eliminate the need for pesticides entirely (AlShrouf, 2017), resulting in a significantly reduced environmental footprint.

Faster growth & higher yields: Precise control of nutrients in soilless systems significantly enhances plant growth and development. Studies have shown that hydroponically grown plants can grow 30-50 per cent faster than those cultivated in soil (Joshi & Joshi, 2018). Aeroponic systems further improve nutrient absorption, leading to healthier plants with improved vitamin and mineral content. This results in higher yields and potentially more nutritious and better-quality produce (AlShrouf, 2017).

Year-round production for food security: Climate-controlled environments in soilless farming allow crops to be grown continuously, independent of seasonal changes. Unlike conventional farming, which relies heavily on weather patterns, soilless systems support consistent, year-round production. This approach ensures a regular and dependable supply of fresh vegetables and fruits throughout the year. As a result, it strengthens food availability and supports long-term food security (Anushree *et al.*, 2024).

Challenges with real time solutions

Limited technical expertise: Soilless farming requires specialized skills in nutrient management, pH/EC control, pest handling, and system maintenance. However, limited technical knowledge and a lack of structured field-level training hinder effective adoption. To bridge this gap, training programs through ICAR-KVKs, Institutes and ATMA should be implemented. Mobile app-based support and hands-on demonstrations can further enhance practical learning and confidence.

High investment cost: Soilless farming demands significant upfront investment for systems like nutrient delivery, lighting, and automation. This high cost makes it difficult for small-scale and young farmers to adopt the technology. The solution lies in developing low-cost designs using local materials and technologies. Providing subsidies through existing agri-schemes can further support adoption, especially in urban and peri-urban areas.

High power consumption: Soilless farming systems require continuous power for pumps, lighting, and climate control. This leads to high energy consumption and dependence on fossil fuels, increasing costs and emissions. To address this, renewable energy sources like solar and wind can be integrated into the system. These solutions reduce operational costs, lower maintenance, and provide clean, sustainable energy.

Limited awareness for scaling up: Awareness, knowledge, and technical understanding of soilless farming remain limited among growers and professionals. To promote its adoption, organizing educational programs, seminars, and training sessions is essential. These initiatives can effectively

build capacity, enhance practical know-how, and spread awareness. Moreover, they help create a skilled workforce capable of managing and maintaining soilless farming systems efficiently.

Conclusion

Soilless farming is not just a futuristic concept- it is a present-day necessity. Hydroponics and aeroponics offer sustainable, scalable, and smart alternatives to traditional agriculture. With the rise of artificial intelligence, automation, and renewable energy integration, these systems are becoming more efficient, resilient, and accessible. As we face growing challenges in food production, water scarcity, and environmental degradation, soilless farming offers a path to produce more with less, ensuring food security for future generations-without depending on the real soil beneath our feet.

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THE FUTURE OF SUSTAINABLE LIVESTOCK FARMING

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Abstract

The global livestock industry plays a crucial role in ensuring food security, economic stability, and rural livelihoods. However, it significantly contributes to environmental challenges such as greenhouse gas emissions, soil degradation, and water pollution. As the environmental impact of traditional animal agriculture practices becomes increasingly evident, there is an urgent call for transformation. Modern strategies centered on animal health, nutrition, waste management, and ecological balance offer promising solutions. By adopting sustainable techniques, livestock farming can evolve into a system that not only supports human needs but also safeguards the environment. This article explores the key strategies and innovations redefining livestock farming for a more sustainable future, emphasizing the balance between productivity and ecological responsibility.

Introduction

Livestock farming has long served as a cornerstone of the global food system, providing essential commodities such as meat, milk, and eggs, while also supporting millions of livelihoods. However, as the demand for animal products intensifies, the industry faces mounting scrutiny regarding its sustainability. Today's agricultural landscape is shifting, emphasizing the necessity of responsible production practices that prioritize ecological preservation and animal welfare alongside productivity.

With increasing concerns over climate change, biodiversity loss, and water contamination linked to livestock operations, the sector stands at a pivotal crossroads. Encouragingly, a range of innovative strategies, rooted in ecological principles, advanced technology, and animal health management, are guiding this transition toward sustainability.

Responsible Livestock Management

Ensuring animal health and optimal nutrition forms the foundation of sustainable livestock systems. Proper animal care not only enhances productivity and welfare but also reduces disease susceptibility. Providing nutritionally balanced diets—rich in energy, proteins, vitamins, and minerals—can minimize the need for therapeutic antibiotics and bolster overall herd resilience.

In addition, stringent biosecurity measures and diligent hygiene practices significantly limit the spread of infectious diseases, thereby safeguarding both animal populations and public health.

Soil Health and Pasture Management

Sustainable livestock production is intrinsically linked to soil health. Implementing improved grazing practices and soil management techniques allows pastures to function as effective carbon sinks, sequestering atmospheric carbon dioxide and enriching soil fertility.

Strategic rotational grazing, complemented by appropriate soil amendments, promotes deep-rooted plant growth, increases organic matter content, and enhances the soil's water-holding capacity. These practices not only mitigate greenhouse gas emissions but also boost pasture productivity, offering long-term benefits for both the environment and farming operations.

Waste Management Innovations

Manure management remains a significant challenge within livestock systems, given its potential to release potent greenhouse gases like methane and nitrous oxide. However, when managed effectively, livestock waste transforms from an environmental hazard into a valuable resource.

Utilizing controlled manure application, anaerobic digesters, and composting techniques reduces emissions while generating nutrient-rich fertilizers. Advanced waste management methods also play a crucial role in preventing pathogen runoff into water systems, thereby protecting both ecological and human health.

Livestock's Role in Climate Change

Methane emissions from ruminant digestion and nitrous oxide from manure decomposition are primary contributors to agriculture's environmental footprint. Their high global warming potential underscores the need for effective mitigation strategies.

Emerging technologies—such as methane-reducing feed additives and selective breeding for low-emission livestock—present promising avenues for reducing the sector's climate impact. With supportive policies and innovative research, livestock farming can become a part of the broader solution to global warming.

Economic Opportunities in Sustainable Livestock

Beyond environmental benefits, transitioning to sustainable livestock practices fosters economic development, particularly in rural areas. According to the United Nations Environment Programme, "green jobs" related to sustainable agriculture—ranging from pasture management to waste treatment—have the potential to revitalize rural economies and alleviate poverty.

As market demand for environmentally responsible products grows, new business models centered around sustainable animal production, environmental auditing, and eco-friendly feed manufacturing are emerging.

Strategies for a Greener Livestock Future

- 1) **Emission Monitoring** : Quantifying methane and nitrous oxide emissions across different farming systems enables the identification of best practices and highlights areas for improvement in climate mitigation efforts.
- 2) **Smarter Nutrition** : Optimizing animal diets through precision feeding enhances resource efficiency, improves animal health, and reduces environmental strain, ultimately supporting more sustainable production systems.
- 3) **Manure Management Solutions** : Transforming manure into a resource via composting and anaerobic digestion significantly cuts emissions, recycles nutrients, and promotes sustainable crop production.
- 4) **Carbon Sequestration through Grazing** : Adopting controlled grazing systems that promote deep-rooted vegetation enhances soil carbon sequestration, offering a natural method for offsetting livestock-related emissions.

- 5) **Economic Analysis** : Evaluating the cost-effectiveness of sustainable practices reveals that, while initial investments may be substantial, the long-term economic benefits, including resilience and efficiency, outweigh short-term costs.
- 6) **Water Resource Conservation** : Careful assessment of livestock water use enables the development of water-saving strategies that reduce environmental stress without compromising productivity.
- 7) **Disease Prevention** : Investments in preventive healthcare—such as vaccination programs, improved biosecurity, and optimal nutrition—reduce reliance on antibiotics and minimize disease outbreaks.
- 8) **Creation of Green Jobs** : Sustainable livestock production generates employment opportunities in emerging sectors like organic feed production, environmental consultancy, and renewable energy generation from waste.
- 9) **Global Knowledge Exchange** : Learning from diverse global livestock practices facilitates the adoption of region-specific solutions, blending traditional knowledge with modern innovations for sustainable outcomes.

Conclusion

Sustainable livestock farming is no longer an abstract concept but a growing reality worldwide. Through integrating science-based nutritional strategies, proactive disease prevention, efficient waste management, and emission reduction technologies, the livestock sector can meet the growing global food demand without exacerbating environmental degradation. Reforming livestock practices is not merely an environmental necessity; it is a moral, economic, and social imperative. The roadmap to a sustainable future demands collective action—smarter systems, healthier animals, thriving soils, and greener economies.

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SUSTAINABLE AGRICULTURE: ECONOMIC CONSIDERATIONS OF INVESTMENT, RETURN, AND EXCHANGE

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Introduction

The global agricultural system is under immense pressure to feed a growing population while preserving ecological balance. Conventional farming, dependent on chemical inputs and monoculture systems, has achieved productivity gains at the cost of soil health, biodiversity, and long-term sustainability. In contrast, Sustainable Agriculture (SA) offers a holistic approach that balances economic viability, environmental stewardship, and social equity.

But for farmers, especially smallholders, economic considerations—costs, returns, and market dynamics—remain crucial. This article examines sustainable agriculture through the lens of economics, focusing on investment patterns, return on investment (ROI), and market exchange mechanisms.

“Sustainability in agriculture is not only an ecological necessity but also an economic opportunity.”
— *FAO, 2020*

What is Sustainable Agriculture?

Sustainable agriculture refers to farming practices that:

- Maintain or improve productivity
- Conserve natural resources
- Enhance ecosystem services
- Are economically viable and socially just

Key Features:

- Crop diversification
- Organic or low-chemical inputs
- Soil and water conservation
- Reduced carbon footprint
- Integrated farming systems

According to the *Brundtland Commission (1987)*, sustainable agriculture must meet present food needs without compromising future generations.

Investment Requirements in Sustainable Agriculture

Shifting from conventional to sustainable farming involves both tangible and intangible investments.

1. Physical Investments

- Composting units

- Drip irrigation systems
- Solar-powered pumps
- Vermiculture and biofertilizer units
- Fencing for agroforestry or organic farming

2. Human Capital Investments

- Farmer training and capacity-building
- Extension services and agro-advisory apps

3. Institutional and Financial Costs

- Certification for organic produce
- Compliance with government schemes

Data Point: Average transition cost to organic farming in India is ₹25,000–₹40,000 per hectare (NABARD, 2022).

Sources of Financing for Sustainable Agriculture

1. Public Sector Support

- Paramparagat Krishi Vikas Yojana (PKVY) for organic farming in India
- Subsidies on solar pumps, composting, and soil health cards

2. Private and NGO Investments

- Microfinance Institutions (MFIs)
- Agri-tech startups (e.g., *Kheyti*, *Ecozen*)

3. Climate Finance

- Green Climate Fund
- Carbon Credit Markets for agroforestry and low-carbon farming

Economic Returns from Sustainable Farming

1. **Yield Stability** : While initial yields may dip during the transition, sustainable systems stabilize over time, with resilience to climate shocks.
2. **Reduced Input Costs** : Savings on chemical fertilizers and pesticides can lower total production costs.
3. **Premium Pricing** : Certified organic or sustainably grown products fetch 20–40% higher prices in niche markets.
Case Study: Sikkim, India—India's first organic state—recorded a 35% increase in farm profits between 2016 and 2021 (Sikkim Govt Report, 2022).
4. **Ecosystem Services as Indirect Returns** : Healthy soil, water retention, pollinator abundance, and carbon sequestration contribute to long-term productivity.

Exchange and Market Considerations

1. **Market Access** : Sustainable products often face limited access to mainstream markets due to lack of aggregation, logistics, and buyer awareness.
2. **Certification and Labeling** : While labels like *India Organic*, *USDA Organic*, or *Fair Trade* increase credibility, they involve additional costs and compliance.
3. **Value Chain Integration** : Producer collectives and Farmer Producer Organizations (FPOs) can help negotiate better prices and access export markets.
Example: *Navdanya* NGO helps small organic farmers market their produce via e-commerce and community-supported agriculture.

4. **Digital Platforms** : Apps like *BigHaat*, *AgriBazaar*, and *Bijak* provide real-time price info, quality checks, and online trading options for sustainable goods.

Cost-Benefit Analysis of Sustainable Agriculture

Traditional vs Sustainable Models:

Parameter	Conventional	Sustainable
Input Cost	High (chemical)	Moderate to low (bio-based)
Yield	High (short-term)	Moderate but stable (long-term)
Market Risk	Medium	Lower with niche markets
Soil Health	Degrades	Improves
ROI (3–5 years)	Volatile	Increasing trend

According to *ICAR (2021)*, sustainable farms in Maharashtra earned 18–24% higher net income after five years of adoption.

Challenges in Economic Adoption

- **Transition Risk**: Delayed benefits discourage adoption.
- **Certification Complexity**: Costly and bureaucratic for smallholders.
- **Consumer Awareness**: Low in rural and semi-urban markets.
- **Credit Barriers**: Traditional banks may hesitate to fund organic transitions.

Policy Recommendations

1. **Long-Term Credit with Moratorium** : Offer 3–5 year moratorium loans with low interest to support transition.
2. **Decentralized Certification** : Encourage participatory guarantee systems (PGS) for community-based organic verification.
3. **Subsidize Risk Mitigation Tools** : Crop insurance for organic farms and weather-index insurance should be promoted.
4. **Market Infrastructure** : Invest in cold chains, e-mandis, and last-mile connectivity for sustainable produce.
5. **Integration in School and Public Procurement** : Link sustainable produce with mid-day meals, hospitals, and public ration systems.

Conclusion

Sustainable agriculture is not only an environmental imperative but also an economic alternative that promises long-term profitability. The transition requires substantial but manageable investments and a shift in market infrastructure. With supportive policies, market reforms, and financial instruments, sustainable farming can move from a niche movement to a national necessity. By accounting for both ecological costs and economic returns, sustainable agriculture creates a resilient foundation for future food systems.

“The future of agriculture is green, but it must also be profitable.” — *IFPRI, 2023*

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THE ART OF PRESERVATION: TEXTILE CONSERVATION FROM FRAGILITY TO PERMANENCE

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Abstract

Beautiful historical documentation of our magnificent history is displayed in textile museums in the shape of robes, accessories, specimens, and fabric. The museum's textiles have endured for a very long time because they were handled, transported, and stored properly. As a result, we can appreciate the need of treating museum textiles with care so that they can be viewed by future generations in the same state as they are today. Because historical fabrics vary widely in terms of composition, structure, and ornamentation, storing them is difficult today. Managing, storing, and showcasing costumes and textiles in a way that keeps them safe and doesn't put them in danger is crucial. This chapter explains the instruments used to handle museum textiles. In this context, certain tools are employed for handling and maintaining such textiles. Additionally, whether moving costumes and fabrics from one room to another or from one continent to another, it must be planned for and executed with the right personnel and equipment. Textile and apparel artifacts in museum collections are highly susceptible to environmental and biological degradation. Condition assessment, repair, and stabilization practices are essential to ensuring their long-term preservation. This paper reviews the methodologies employed in textile conservation, highlighting recent advancements, challenges in the field, and case studies from Indian and international museums.

Key Words: Textiles, Conservation, Assessment, Stabilization, Preservation, Heritage, Sustainability

Introduction

Textile and apparel artifacts in museums embody rich cultural, historical, and technological heritage. However, their organic composition makes them vulnerable to various forms of deterioration such as light, humidity, pests, pollutants, and mechanical stress. Museum professionals are tasked with the dual responsibility of preserving these artifacts and maintaining their display viability. Conservation practices have evolved from reactive restoration to preventive conservation, focusing on minimal intervention and long-term stability (Kaur, 2021).

Textiles and garments preserved in museums are more than just remnants of the past—they are tactile expressions of human creativity, identity, and social history. Each stitch, weave, and dye used in these objects reflects the technological sophistication, aesthetic values, and cultural beliefs of a particular time and place. Whether it's a centuries-old ceremonial robe, a handwoven tapestry, or a piece of everyday clothing, these artifacts serve as irreplaceable links to the traditions and lives of those who came before us.

However, the organic materials that give textiles their richness—such as cotton, wool, silk, and natural dyes—also make them inherently fragile. Over time, exposure to light, fluctuating humidity, air pollutants, biological pests, and even the stresses of display and handling can lead to discoloration, fibre breakdown, structural damage, and loss of detail (Phipps, 2011). This

vulnerability poses complex challenges for museums, where the goals of preservation, research, education, and public access must be delicately balanced (Lunning).

As a response to these challenges, the field of textile conservation has undergone a significant transformation. Once focused primarily on reactive restoration—repairing damage after it occurred—contemporary conservation now emphasizes preventive care (Kieft & de Groot, 2006). This proactive approach seeks to slow or prevent deterioration through controlled environments, careful handling, informed display methods, and the use of archival storage materials. Preventive conservation recognizes that even minimal interventions can have long-term impacts, and that preserving original materials and intent is as important as halting decay.

Moreover, the discipline is increasingly interdisciplinary, incorporating advances in material science, imaging technology, and cultural studies. Techniques such as multispectral imaging, digital microscopy, and fibre analysis allow conservators to assess condition and composition without invasive sampling (Textile Museum of Canada, n.d.). At the same time, ethical considerations are becoming more central, particularly with regard to garments that hold ceremonial, religious, or indigenous significance. In such cases, collaborative conservation practices—where conservators work with source communities—are vital for respecting cultural values and narratives (Brennan, 2021).

In an era where museums are reimagining their roles as stewards of both heritage and sustainability, textile conservation stands at the intersection of tradition and innovation. It is a field that demands both technical precision and cultural sensitivity. Through thoughtful conservation practices, fragile fibres are not only preserved but recontextualized, ensuring that they continue to educate, inspire, and connect us to the past (Lunning).

This paper explores the philosophies, practices, and evolving challenges of textile and garment conservation in museums. It highlights how conservation professionals navigate the delicate path from fragility to longevity—transforming vulnerable organic materials into lasting legacies.

Condition Assessment

The first step in textile conservation is a detailed condition assessment. This includes visual inspection, photographic documentation, fibre analysis, and environmental monitoring. According to the thesis by Gurmeet Kaur (2021), an effective assessment also involves historical research and previous treatment records to understand an artifact's provenance and vulnerabilities. Digital tools, such as Digital Image Correlation (DIC), are being increasingly used to detect micro-level damages non-invasively (Colombini *et al.*, 2023a).

The physical condition is usually recorded in a condition report, which includes fibre integrity, color fading, presence of stains, tears, and previous repairs. Museums in Northern India, for example, use checklists and photographic logs to routinely assess textile conditions (Kaur, 2021). Additionally, ultraviolet (UV) light inspection is used to identify dye degradation and contamination, while microscopic analysis helps identify mold, insect damage, and fibre deterioration (Canadian Conservation Institute, 2022). The incorporation of X-ray fluorescence (XRF) and Fourier-transform infrared spectroscopy (FTIR) is increasingly being adopted for non-destructive analysis (Badanayak *et al.*, 2022).

Repair and Stabilization Techniques

Repair and stabilization focus on arresting further degradation while maintaining the artifact's historical integrity. Cleaning is a preliminary yet crucial step; however, it must be cautiously done to

avoid irreversible damage. Maria Perla Colombini (2023) compared wet and dry-cleaning procedures on historical tapestries, finding that dry methods reduced fibre stress.

Support stitching, patching with similar fibres, and mounting techniques are common repair practices. In India, traditional methods are sometimes integrated with modern practices to ensure cultural sensitivity. For example, the use of khadi cloth for lining fragile sarees, or natural dyes in retouching areas of loss, showcases a blend of indigenous and scientific methods (Badanayak *et al.*, 2022). Stitching methods such as couching, laid-and-couched work, and overlay support are selected based on the condition and weave type. Adhesive-stabilization with heat-activated films like Beva 371 is used in Western practices, while Indian conservators tend to rely more on stitching due to the risks associated with adhesives in high humidity environments (Gorman, 2009).

Newer stabilization materials such as polyester nets or adhesive-support films are used in conjunction with hand-sewing to stabilize weak areas. Textile mounting for display involves padded boards or slanted mounts to reduce mechanical stress. Vacuum tables are also used in advanced conservation labs to clean and support large fragile textiles (Timár-Balázs & Eastop, 1998).

Preventive Conservation

Preventive conservation aims to create a stable environment that slows down the rate of deterioration. Temperature (around 20°C), relative humidity (50-55%), light levels (below 50 lux), and pest management are critical parameters (Canadian Conservation Institute, 2022). A study by Bhatt (2022) on Uttar Pradesh museums showed that many institutions struggle with maintaining these standards due to budgetary and infrastructural limitations.

Custom storage solutions such as acid-free boxes, flat storage, or padded hangers are used to prevent mechanical stress. Use of interleaving tissues, muslin covers, and breathable plastic containers are common (Badanayak *et al.*, 2022). Integrated pest management (IPM) plans involve the use of pheromone traps, regular inspections, and non-toxic pest control methods.

An intervention model proposed by Dr. Gurmeet Kaur emphasizes risk assessment, staff training, and community participation to enhance the conservation framework in small museums. Regular training workshops for museum personnel and the inclusion of local craftspeople can also help maintain culturally relevant conservation practices (Brennan, 2021).

Challenges and Future Directions

Despite advancements, textile conservation faces significant challenges, especially in developing countries. These include limited funding, lack of trained conservators, and inadequate documentation practices. In many regional museums, textile artifacts are stored without proper inventory or conservation protocols, leading to irreversible loss. Moreover, climatic conditions in tropical countries pose an added risk due to high humidity and pest activity (Bhatt, 2017).

Research in nanotechnology and sustainable conservation materials is opening new avenues. For example, the use of nano-silica for cleaning and anti-microbial coatings for textiles is being explored (Colombini *et al.*, 2023). Digital archiving and virtual modeling of textile artifacts are also emerging as complementary conservation tools. AI-based condition monitoring and automated damage recognition through image analysis hold potential for large-scale collection management (Wiki contributors).

International collaborations, such as between Indian institutions and European conservation bodies, have proven beneficial in knowledge exchange and resource sharing (Lunning, E.). The future of textile conservation lies in creating resilient infrastructures, integrating science with tradition, and building a skilled workforce through education and policy support (Badanayak *et al.*, 2022).

Conclusion

Textile conservation in museums plays a vital role in preserving cultural and historical heritage. These artifacts, made from fragile organic materials, are highly susceptible to environmental and biological deterioration. Effective conservation involves condition assessment, careful stabilization, and preventive care to ensure long-term preservation. Modern conservation combines scientific techniques with traditional methods, especially in culturally rich contexts like India. However, challenges such as limited funding, lack of trained professionals, and climatic risks continue to impact conservation efforts. To safeguard these artifacts for future generations, museums must invest in skilled personnel, sustainable materials, and interdisciplinary approaches. By doing so, fragile textile fibers can be transformed into lasting legacies that continue to educate and inspire.

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TOWARDS RESPONSIBLE TEXTILE CONSERVATION: DOCUMENTATION, INTERVENTION, AND INNOVATION

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Abstract

Textile conservation involves preserving the structural and historical integrity of fabrics through particular documentation, careful handling, and planned pre-preparation. This paper discusses the importance of recording textile conditions, including written reports, photographic imaging, and technical analysis. Proper handling techniques, such as using gloves and minimal direct contact are essential for protecting fragile textiles. Pre-preparation steps like condition assessments and surface cleaning help prevent further deterioration. The paper also addresses the balance between preserving authenticity and restoration with attention to emerging technologies like laser cleaning and non-invasive repair methods. Additionally, sustainability in conservation is highlighted with a focus on eco-friendly materials and preventive strategies. This review provides a comprehensive look at the early stages of textile conservation, integrating ethics, technology and sustainability.

Introduction

Textile conservation is essential for preserving the cultural and historical significance of fabrics. It integrates scientific analysis, historical research, and practical preservation techniques. The conservation process begins with documenting textile conditions, followed by careful handling to minimize damage. Pre-conservation steps such as cleaning and condition assessments are crucial for maintaining textile integrity. With advances in technology and a focus on sustainability, modern textile conservation has evolved to offer safer and more effective methods. This paper explores the essential stages of textile conservation, focusing on documentation, handling, and pre-preparation techniques (Madhu *et al.*, 2015).

Objectives

- To explore the importance of documentation, pre-conservation methods and handling in textile conservation.
- To explore the challenges and innovations in textile conservation

Recording in Textile Conservation

Importance of Documentation Recording textile conditions provides a reference for conservation decisions and future research. Comprehensive documentation helps in tracking deterioration, planning treatments, and maintaining historical integrity (Madhu *et al.*, 2015).

Methods of Recording

- **Written Documentation:** Includes detailed condition reports, treatment history, and historical context.
- **Photographic Recording:** High-resolution imaging under visible, ultraviolet (UV), and infrared (IR) light to capture details of damage and previous restorations.

- **Technical Analysis:** Involves spectroscopy, microscopy, and other analytical methods to determine fibre composition, dye stability, and degradation levels.
- **Sketching and Mapping:** Diagrams indicating stress points, weak areas, and prior repairs aid in conservation planning.

Handling Guidelines for Textile Artifacts

Proper Handling Practices

- **Use of Gloves:** Nitrile or cotton gloves to prevent oil and dirt transfer.
- **Minimal Direct Contact:** Supporting textiles with acid-free tissue or soft tools.
- **Controlled Movement:** Using multiple handlers for large or delicate textiles to avoid strain.
- **Environmental Precautions:** Ensuring clean, stable conditions with minimal light and pollutant exposure during handling.

Tools for Safe Handling

- Soft brushes and tweezers for delicate manipulation.



Figure. 1 Using gloves and soft brushes during conserving

- Acid-free tissue paper and padded supports for structural reinforcement.



Figure. 2 Using acid-free tissue paper during conserving

- Custom mounts and support frames for display or transport.



Figure. 3 Beaded cap on storage and display mount

Pre-Preparations Before Conservation

Initial Condition Assessment Conducting a thorough visual and technical inspection to determine the textile's stability, weaknesses, and necessary interventions.

Surface Cleaning and Stabilization

In textile conservation, it refers to the initial steps taken to remove loose dirt and debris and to reinforce fragile areas before any major conservation treatment. (Dancause *et al.*, 2024)

- **Dry Cleaning:** Use of soft brushes and low-suction vacuuming to remove surface dust.
- **Colour fastness Testing:** Ensuring dyes and fibres react safely to moisture or solvents before wet cleaning.
- **Temporary Supports:** Applying netting or adhesive backing to fragile areas before further treatment.
- **Pest Inspection:** Identifying insect damage and applying non-toxic pest control measures.

Challenges and Innovations in Textile Conservation

Ethical Considerations in Conservation

Balancing intervention with preservation to maintain authenticity (Eastop 2009).

i) Preserving Authenticity vs. Restoration

- **Preserving Authenticity:** This approach focuses on maintaining the textile in its current state without significant alterations.
 - Minimal interventions are made to stabilize and prevent further deterioration.
 - Original materials, weaves, and colours are left untouched, even if faded or damaged.
 - Used in cases where historical integrity is more important than visual appeal (e.g., archaeological textiles, sacred garments).
- **Restoration:** This approach involves actively repairing and reconstructing parts of the textile to restore its original appearance.
 - Damaged sections may be re-woven, re-dyed, or structurally reinforced.
 - Restoration is used when an artefact needs to be displayed in a more visually intact form, such as in museum exhibits. However, excessive restoration can lead to a loss of authenticity if too many modern materials are introduced.

ii) Consent and Cultural Sensitivity: Textiles often hold deep cultural, religious, or ancestral significance, making their conservation a sensitive issue. Consent from relevant communities is crucial before making any conservation decisions, especially for sacred, indigenous, or heritage textiles.

- Some cultures prefer natural aging over artificial preservation.
- Collaboration with cultural representatives ensures that conservation aligns with traditional values.
- Ethical conservators respect community beliefs and traditions while preserving textiles.
- Example: Indigenous ceremonial garments may require special handling protocols or limited restoration to honor cultural practices.

iii) Balancing Intervention and Preservation: The goal of textile conservation is to stabilize artefacts without over-altering their historical integrity. This balance ensures the textile is protected for the future while maintaining its authenticity.

- Minimal intervention prevents unnecessary changes while reinforcing weak areas.

- Reversible methods allow future conservators to undo treatments if needed.
- Conservation vs. Restoration: Some textiles need only preventive care, while others require repairs to be safely displayed or studied.
- Example: A fragile 18th-century silk gown may be supported with a discreet backing instead of full restoration to keep its original materials intact.

Technological Advancements:

Microfading Analysis

A non-destructive technique used to predict how textiles will fade over time. It exposes a tiny area of the fabric to controlled light to simulate long-term exposure. It helps conservators decide safe light levels for museum displays. It prevents irreversible damage by ensuring textiles aren't overexposed to light (Lee, 2015).

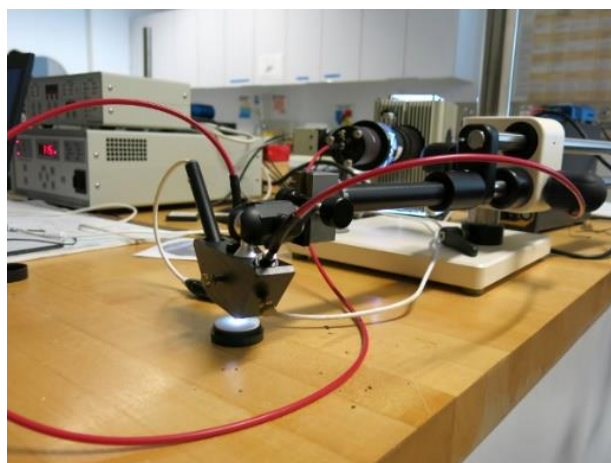


Figure. 4 A close look at the beam of light emitted by the microfading tester (Lee, 2015)

Example: Used in museums to determine if fragile fabrics can be exhibited under certain lighting conditions.

Laser Cleaning Applications

Laser cleaning uses focused beams to remove dirt, soot, or old coatings without damaging delicate fibers. It's ideal for embroidered, ancient, or painted textiles. This chemical- and water-free method works layer by layer, preserving fine details and making it safe for moisture-sensitive materials (Tupuola, 2019).

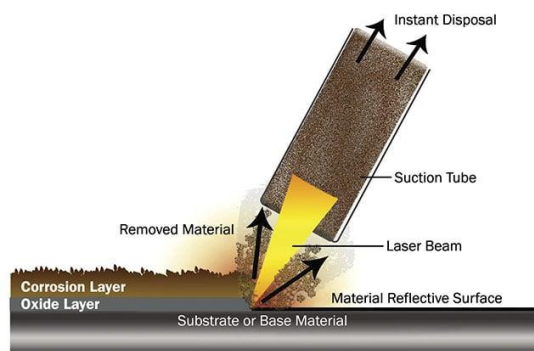


Figure 5. An illustration of the laser cleaning process (Tupuola, 2019)

Example: Used in restoring historic tapestries or textiles with delicate gold embroidery.

Non-Invasive Repair Methods

The aim is to strengthen textiles without causing permanent alterations. Common techniques include adhesive supports using conservation-grade adhesives, minimal-intervention stitching with ultra-fine thread, and sheer overlays that protect delicate textiles with transparent support fabric. These methods preserve the original material while enhancing structural integrity.

Example: A deteriorating historic silk robe may be stabilized with a sheer net overlay instead of direct stitching.

Sustainability in Conservation

Sustainability in conservation involves using eco-friendly materials like biodegradable adhesives and natural fibres, along with preventive strategies such as controlling light, humidity, and temperature. These practices reduce environmental impact while preserving textiles with minimal intervention.

Conclusion

Textile conservation is a critical practice that combines documentation, careful handling, and strategic pre-preparation to ensure the preservation of fabrics with historical and cultural value. By focusing on detailed recording and appropriate handling techniques, conservators can prevent further deterioration and maintain the authenticity of textiles. Pre-conservation methods play an essential role in stabilizing textiles before any major intervention. As technology advances, the field continues to evolve, offering new tools and sustainable practices that enhance the efficiency and effectiveness of conservation efforts. Ultimately, a thoughtful, systematic approach to textile conservation is vital for safeguarding these materials for future generations.

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HOW TO GENERATE RANDOM NUMBERS IN MICROSOFT EXCEL ?

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Abstract

Random number generation is a fundamental process in any kind of research such as cryptography, simulations, statistical analysis, and data science. Microsoft Excel, plays a major role for generating random numbers and making it a convenient tool for users requiring stochastic data. This article examines the mechanisms of random number generation in Excel, focusing on the RAND, RANDBETWEEN and RANDARRAY functions, their applications, and inherent limitations. Additionally, it explores techniques for enhancing randomness, such as utilizing the Analysis ToolPak and advanced pseudo-random algorithms.

Keywords: Random number generation, MS Excel, Statistical simulations

Introduction

Random number generation is a process that generates a sequence of values or individual values that are unpredictable and appear random. It is crucial for various applications such as process in computing, any kind of statistics, cryptography, simulations, and gaming.

Types:

The methods for generating random numbers fall broadly into two categories:

1. **Physical (true) random number generation:** Generate numbers from a physical process, such as atmospheric noise or radioactive decay, making them truly random and unpredictable.
2. **Computational (pseudorandom) number generation:** Use algorithms to generate numbers that appear random but are deterministic in nature.

Random number generation in MS Excel:

Random number generation is a powerful feature in Microsoft Excel, enabling users to simulate data, create sample datasets, assign random values and much more. Excel provides several built-in

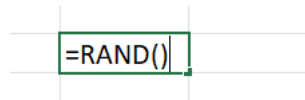
functions for generating both random decimals and integers, as well as arrays of random numbers for advanced needs.

1. **RAND ()**: Generates random decimal numbers between 0 and 1.
2. **RANDBETWEEN ()**: Produces random integers between two specified values.
3. **RANDARRAY ()**: Creates arrays of random numbers, with options for decimals or integers and custom ranges.

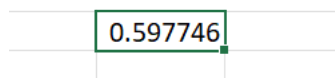
I) **RAND()**: Generating Random Decimals

- The RAND() function returns a random decimal number greater than or equal to 0 and less than 1.
- To use it, simply enter =RAND() in any cell and press Enter. Each time the worksheet recalculates, the number will change.

STEP 1: Type the command in any of the cell



STEP 2: Hit enter to get a random decimal number



Custom Range:

To generate a random decimal between any two numbers (a and b), use the formula:

$$=RAND() * (b - a) + a$$

Whereas,

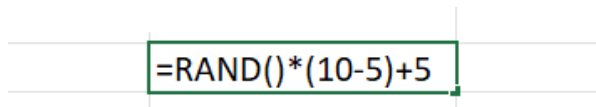
b – maximum value

a – minimum value

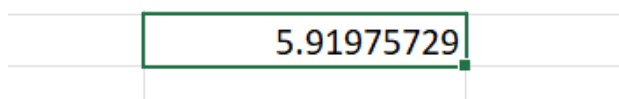
Example:

=RAND() * (10 - 5) + 5 will give a random decimal between 5 and 10.

STEP 1: Type the command in any cell



STEP 2: Hit enter to get a random decimal number between the specified numbers



Locking Values:

If you want to keep the generated number fixed, copy the cell and use Paste Special > Values, or press F9 while editing the formula to convert it to a static value.

II) RANDBETWEEN(): Generating Random Integers

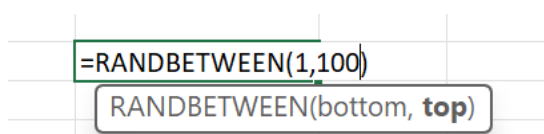
- RANDBETWEEN() generates a random integer between two specified limits.
- This function is especially useful for tasks that require whole numbers, such as assigning random IDs or simulating dice rolls.

=RANDBETWEEN(*lower_limit*, *upper_limit*)

Example:

=RANDBETWEEN(1, 100) generates a random integer between 1 and 100.

STEP 1: Type the command specifying upper and lower limit



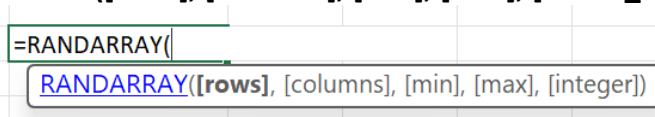
STEP 2: Hit enter to get a random whole number between the specified limit



III) RANDARRAY(): Generating Arrays of Random Numbers

- RANDARRAY() can generate multiple random numbers at once, either as decimals or integers. The syntax is:

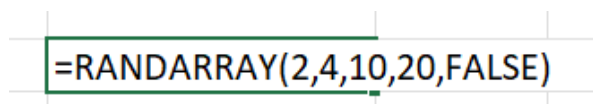
=RANDARRAY([rows], [columns], [min], [max], [whole_number])



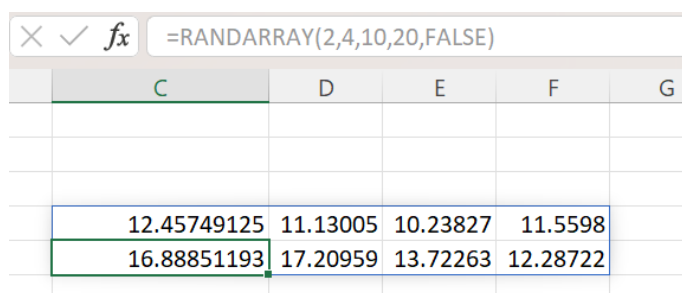
Example:

- To generate a 2x4 array of random **decimals** between 10 and 20:
=RANDARRAY(2, 4, 10, 20, FALSE)

STEP 1: Type the command specifying number of rows, columns, upper, lower limit and decimal



STEP 2: Hit enter to get an array of random **decimal** numbers

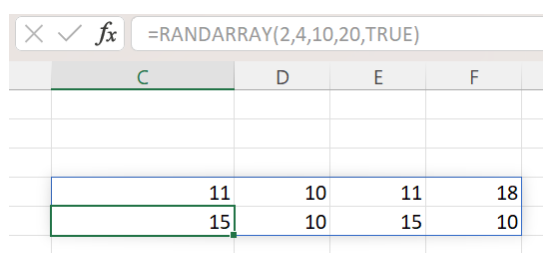


- To generate a 2x4 array of random **integers** between 10 and 20:
=RANDARRAY(2, 4, 10, 20, TRUE)

STEP 1: Type the command specifying number of rows, columns, upper, lower limit and integer

=RANDARRAY(2,4,10,20,TRUE)

STEP 2: Hit enter to get an array of random integer numbers



The screenshot shows the Excel formula bar with the formula =RANDARRAY(2,4,10,20,TRUE). Below the formula bar, a 2x4 array of random integers is displayed in cells C3:F4. The values are: Row 1: 11, 10, 11, 18; Row 2: 15, 10, 15, 10.

	C	D	E	F
	11	10	11	18
	15	10	15	10

Summary of Excel's Random Number Functions

Function	Output Type	Range	Excel Version
RAND()	Decimal	$0 \leq x < 1$ (customizable)	All versions
RANDBETWEEN()	Integer	User-defined min and max	All versions
RANDARRAY()	Decimal/Integer	Rows, columns, min, max	Excel 365, 2021+

Conclusion

Random number generation in Microsoft Excel offers a practical and accessible way to simulate variability and perform unbiased sampling across a wide range of fields. In fisheries research, it can be used to randomly select fish tanks, sample fish populations or populations ensuring objectivity. Other fields like education, healthcare, and business also use it for unbiased testing and simulations. It's a simple yet powerful tool for adding randomness to real-world tasks.

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PODCASTING IN AGRICULTURE: A MODERN TOOL FOR KNOWLEDGE DISSEMINATION

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Introduction

In the era of digital communication, podcasting has emerged as an influential and accessible medium for information dissemination. Originating as a simple audio blogging tool, podcasts have now become an integral part of modern learning systems, including in agriculture. Podcasts provide a unique opportunity to bridge the knowledge gap between agricultural scientists, policymakers, and farmers, particularly in areas where internet bandwidth is low but mobile usage is high.

This article explores the scientific and practical relevance of podcasting in agriculture, its benefits, applications, challenges, and future potential.

What is a Podcast?

A podcast is a digital audio file made available on the internet for streaming or download. Podcasts are typically episodic and can cover a wide range of topics. In agriculture, podcasts serve as platforms for:

- Sharing scientific research and updates.
- Discussing farming techniques.
- Providing market intelligence and weather forecasts.
- Showcasing success stories.

They can be accessed via smartphones, feature phones (with IVR-based systems), radios, and computers, making them versatile tools for rural communication (Barman *et al.*, 2024).

Scientific relevance of podcasts in agriculture

1. Knowledge mobilization

Podcasting helps translate complex scientific knowledge into **farmer-friendly language**. Researchers, extension officers, and agri-entrepreneurs can:

- Disseminate research findings.
- Provide best practices on crop management, pest control, and climate-smart agriculture.
- Share insights on government schemes and subsidies.

2. Behavioural change communication (BCC)

Podcasts support BCC by:

- Repeating messages at regular intervals.
- Using **local languages and dialects**.
- Incorporating narratives and interviews that resonate with rural listeners.

3. ICT for development (ICT4D)

Podcasting aligns with the principles of **Information and Communication Technologies for Development**, leveraging mobile networks to promote sustainable farming.

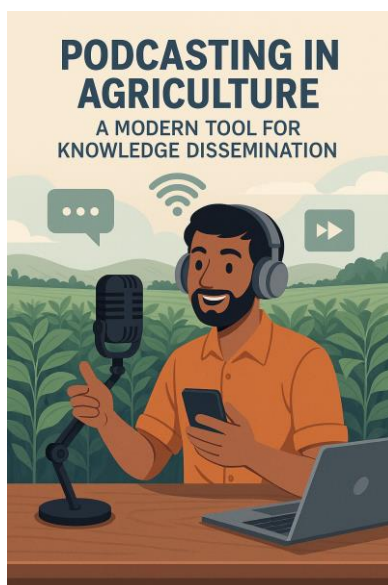


Figure 1: Podcasting in Agriculture

Advantages of podcasting in agriculture (Barman *et al.*, 2024)

1. Accessibility

- Can be played anytime, even offline.
- Ideal for farmers with low literacy.
- Compatible with basic mobile phones (via call-in numbers).

2. Cost-effective and scalable

- Requires low production costs.
- Scalable across regions with minimal investment.

3. Trust and familiarity

- Local voices and languages enhance **credibility and trust**.
- Familiar tone improves engagement.

4. Supports lifelong learning

- Farmers can stay updated on seasonal practices and innovations.
- Can supplement formal extension services.

Challenges in implementation

- **Digital divide:** Not all farmers have access to smartphones or internet.
- **Lack of awareness:** Many rural communities are unaware of podcasts as a learning tool.
- **Language diversity:** Need for multi-language content creation.
- **Content credibility:** Ensuring scientifically accurate and unbiased information.

Future directions and recommendations

1. Integration with extension systems

- Combine podcasts with Krishi Vigyan Kendras (KVKs), eNAM, and Agri Clinics.

2. Training content creators

- Equip extension agents and young farmers with podcast production skills.

3. Multi-platform dissemination

- Use WhatsApp, Telegram, and voice-based AI to reach wider audiences.

4. Public-Private Partnerships

- Collaborate with telecom providers, radio networks, and agricultural universities.

5. Monitoring and feedback

- Collect listener feedback to assess learning outcomes and improve content.

Conclusion

Podcasting is an innovative, inclusive, and scalable tool that complements traditional agricultural extension mechanisms. With strategic support and technological adaptation, it holds immense potential to transform the way farmers access and apply agricultural knowledge in India and beyond. As agriculture adapts to digital transformation, the humble podcast may very well become a powerful voice in every farmer's ear.

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HEALTH AND WEALTH BENEFITS OF GINGER THROUGH POST HARVEST MANAGEMENT

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Summary

Post-harvest management of ginger offers numerous health benefits, including anti-inflammatory, antioxidant, and anticancer properties. However, challenges like microbial spoilage and moisture loss can lead to quality and economic losses. Effective strategies include proper harvesting, curing, optimal storage, and processing techniques to maintain ginger's quality and health benefits while minimizing losses from post-harvest deterioration.

Introduction

Ginger (*Zingiber officinale*) is a flowering plant whose rhizome, ginger root or ginger, is widely used as a spice and a folk medicine. It is an herbaceous perennial which grows annual pseudostems (false stems made of the rolled bases of leaves) about a meter tall bearing narrow leaf blades. The inflorescences bear pale yellow with purple flowers and arise directly from the rhizome on separate shoots. In 2017, global production of ginger was 3.3 million tonnes, led by India with 34% of the world total. Nigeria, China, and Indonesia also had substantial production (Syeda, *et al.*, 2019).

Ginger is a globally significant spice and medicinal plant, extensively cultivated in tropical and subtropical regions, including Africa, Asia, and Latin America. Its versatile applications in culinary arts, traditional medicine, and pharmaceutical industries underscore its economic importance. Ginger is a cornerstone of African traditional medicine, where it is utilized for treating ailments such as colds, nausea, and inflammatory conditions, vomiting, rheumatism, baldness, respiratory diseases and bleeding disorders (Kelly *et al.*, 2009; Adetuyi *et al.*, 2024). Globally, ginger is acclaimed for its bioactive compounds, particularly gingerols and shogaols, which possess antioxidant, anti-inflammatory, and antimicrobial properties (Chen *et al.*, 2023).

Effective post-harvest management strategies are critical to address these challenges which include proper curing, temperature and humidity control during storage, and the application of biocontrol agents and natural coatings to reduce microbial spoilage (Akinbile and Abdulrahman, 2024). Innovations in packaging and storage technologies are also pivotal in extending shelf life and maintaining quality, especially for smallholder farmers and exporters reliant on this valuable commodity.

Uses of Ginger

Culinary Uses of Ginger

Ginger is widely used in cooking for its distinct flavor and aromatic qualities. In African cuisine, ginger is a common ingredient in soups, stews, and beverages. In Nigeria, for instance, ginger is often used to prepare traditional drinks like 'zobo', a popular hibiscus tea, and spicy soups like 'pepper soup' (Nwofia *et al.*, 2020). East African countries, such as Kenya and Ethiopia, frequently use ginger in spiced tea, known as 'chai', and in meat dishes (Gakuya *et al.*, 2011). Ginger plays a crucial role in

Asian cuisine, particularly in India and China, where it is used in curries, sauces, and pickles (Sharma & Sangha, 2021). In Europe and North America, ginger is a popular ingredient in baked goods, such as gingerbread, and in beverages like *ginger ale* and *ginger tea* (Masuda *et al.*, 2022).

Medicinal Uses of Ginger

The medicinal applications of ginger are well-documented, both in traditional African medicine and global herbal practices. In many African countries, ginger is used to treat digestive disorders, colds, and respiratory infections (Maregesi *et al.*, 2021). It is also believed to have aphrodisiac properties in certain African cultures, where it is used to enhance sexual health (Ogwal-Okeng *et al.*, 2020). Ginger has been recognized for its anti-nausea properties, particularly in managing motion sickness and morning sickness during pregnancy (Viljoen *et al.*, 2014). A study in Japan highlighted the use of ginger for reducing chemotherapy-induced nausea - Gingerols the key ingredients responsible for the activity have shown pharmacological effect (Krim *et al.*, 2013) further supporting its reputation as a potent anti-emetic by enhancing intestinal motility and inhibiting serotonin receptors. It stimulates peripheral anti-cholinergic and ant-histaminic receptors and antagonises 5- hydroxytreptamine receptors in the GIT (Gull *et al.*, 2012; Yamamoto *et al.*, 2020).

Health Benefits of Ginger

Anti-Inflammatory and Antioxidant Properties

Ginger contains bioactive compounds like gingerol and shogaol, which have powerful anti-inflammatory effect by suppression of PG synthesis and also interference in cytokine signalling (Mahmoud *et al.*, 2012) and antioxidant activity due to its oil which has protective effect on DNA damage which they have demonstrated in many cell culture (Mahmoud *et al.*, 2012; Al-Awwadi, 2010). These compounds can help reduce oxidative stress in the body, a contributor to chronic diseases (Al-Amin *et al.*, 2021). In Nigeria, traditional healers use ginger to treat joint pain and inflammation, aligning with research that suggests ginger's efficacy in managing osteoarthritis symptoms (Awolumate *et al.*, 2022).

Digestive and Gastrointestinal Effects

Ginger is well-known for its digestive benefits. It can help alleviate gastrointestinal discomfort, stimulate digestion, and relieve bloating (Hashimoto *et al.*, 2018) and is a common remedy for treating indigestion, stomachaches, and studies confirm its effectiveness in enhancing digestive function (Maregesi *et al.*, 2021).

Ginger is very useful in the treatment of several gastrointestinal diseases including peptic and duodenal ulcer. Ginger is useful due to its anti-inflammatory properties. Ginger acts and protects gastric mucosa against several ulcerogenic agents due to its antioxidant activities (Gull *et al.*, 2012; Dugasani *et al.*, 2010).

Antimicrobial Properties and Immune System Support

Due to its phenolic compounds, ginger has shown excellent antimicrobial properties and effective in controlling virus, bacteria, fungal disease. In many countries, ginger is used to preserve food (Liao *et al.*, 2012; Chen *et al.*, 2009). Ginger is often used in Africa to strengthen the immune system, particularly during flu season or in cases of respiratory infections. It is believed that the warming properties of ginger help to fend off colds and flu (Adeniyi *et al.*, 2021). This belief is supported by research showing that ginger has antimicrobial properties that can enhance immune function (Ravindran and Babu, 2016).

Cardiovascular Health and Anticancer Potential

Ginger has cardiovascular benefits, including the ability to lower blood pressure, reduce cholesterol levels, and prevent blood clots. Studies also highlight ginger's ability to lower lipid levels, and improve overall heart function (Omodamiro *et al.*, 2017; Appiah *et al.*, 2019). Ginger enhances blood circulation throughout the body by stimulation of the heart muscle and by diluting circulating blood. This enhances cellular metabolism and helps to relief cramp and tension (Ernst and Pittler, 2000; Chaiyakunapruk *et al.*, 2006). Similarly, recent studies have investigated ginger's potential anticancer properties. Compounds like gingerol and paradol have demonstrated anticancer activity by inhibiting the growth of cancer cells and inducing apoptosis (Singh *et al.*, 2023).

Modern Applications of Ginger

The global market for ginger continues to grow, driven by its culinary, medicinal, and health benefits. In East Africa, ginger farming has become a significant agricultural activity, contributing to both local economies and exports (Muthoni and Nyamongo, 2009). Ginger supplements and extracts are widely available in health food stores, promoting its use as a natural remedy for various ailments (Lee *et al.*, 2021). Additionally, ginger is now being used in modern skincare products due to its anti-inflammatory and antioxidant properties, highlighting its versatility beyond the kitchen (Patil *et al.*, 2023). Ginger oil, commonly used in aromatherapy, is believed to promote relaxation, reduce stress, and alleviate muscular pain.

POSTHARVEST PROBLEMS

Dehydration is the most common problem associated with young or "baby" ginger. During handling, the rhizomes lose their sheen, darkens rapidly and shriveling occurs after the loss of about 10% of harvest weight. Holding ginger at a less than optimal temperature and relative humidity (RH) accelerates postharvest decay because as the temperature increases, the rate of sprouting grows. Ginger rhizomes are very sensitive to chilling injury or low temperature breakdown if stored below 12°C (54°F). Shriveling/desiccation is another common postharvest disorder of ginger held under low relative humidity (RH) conditions (i.e. less than 65% RH) (USAID, 2004).

Postharvest Management

Rhizomes should be handled with care to prevent injury when harvested. According to FAO (2002), fresh rhizomes should be washed from dirt. Ginger intended for long term storage should be washed immediately after harvest and then cured (Kc *et al.*, 2009). Matured ginger rhizomes can be stored at 12 to 14°C (54 to 57°F) with 85 to 90% RH for 60 to 90 days because storage at 13°C (55°F) with 65% RH leads to extensive dehydration and a wilted appearance (Paull and Chen, 2015). Curing helps to heal the injured, scratched and cut rhizomes wounds by keeping for 3-4 days under the shade at a desirable temperature of 22°C to 26°C (Acharya, 2012). Furthermore during sorting, damaged and injured rhizomes should be removed and the remaining marketable rhizomes should be stored according to size (USAID, 2004).

Conclusion

Ginger is a spice of commercial and medicinal importance. It is valued because of its aroma and pungency and has been used through ages in almost all systems of medicine against many maladies due to its medicinal properties. However, the rapid dehydration during postharvest period is one of the most critical problems that hinder its commercialization. Application of appropriate techniques for postharvest management of ginger could minimize losses, enhance quality and increase marketability of the spice both locally and internationally.

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SUSTAINABLE ORGANIC FARMING AND ITS FOOD DERIVATIVES: NURTURING HEALTHY EATING HABITS FOR FUTURE GENERATIONS

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Modern agriculture has evolved significantly, driven by high-yield hybrids, advanced technologies, and innovative pesticides and fertilizers. However, the lack of education among farmers and the imbalanced use of these technologies have raised serious concerns about their impact on human health and the lifestyles of future generations. In response to these issues, organic integrated farming and its food derivatives are gaining popularity, offering a wake-up call for healthier living.

The Shift to Organic Farming: A Necessity for Sustainability

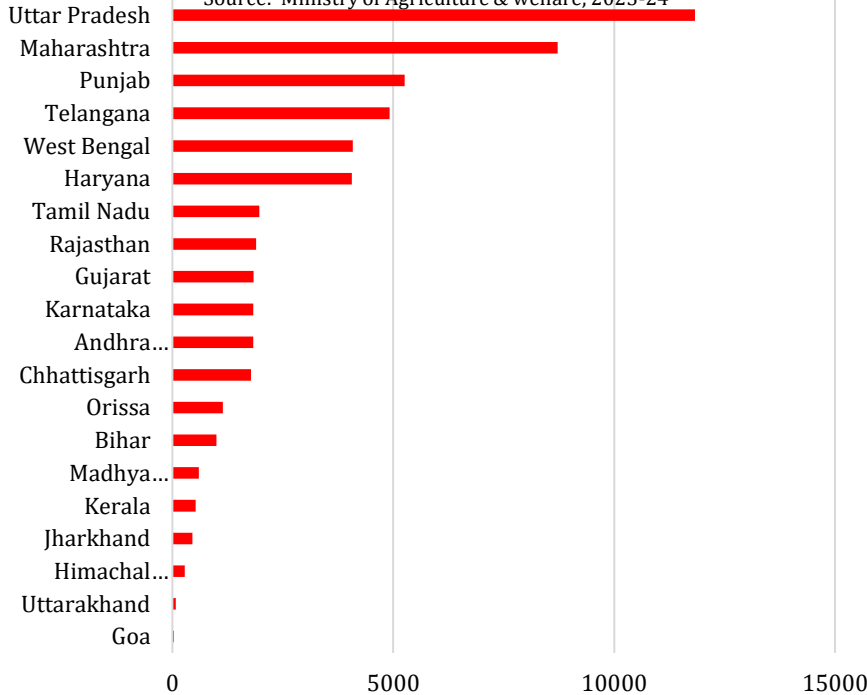
Organic farming focuses on cultivating crops using biofertilizers and natural pesticides, promoting balanced ecosystems and maintaining soil health. This approach contrasts with the conventional farming practices that were shaped by the Green Revolution. While the Green Revolution significantly boosted crop yields, it also resulted in harmful environmental and ecological consequences due to the excessive reliance on chemical fertilizers and pesticides. This has led to issues such as soil erosion, reduced microbial diversity, and disrupted ecological balance, resulting in new pests and disease outbreaks. The increasing dependence on these chemicals underscores the need to shift toward organic farming practices to promote environmental sustainability, preserve biodiversity, and ensure healthier food options for future generations.

Health Risks of Excessive Pesticide Usage

Pesticide residues in food, especially vegetables, fruits, and grains, pose a significant health risk. High pesticide exposure can cause acute poisoning, while prolonged low-level exposure can lead to chronic health issues such as cancer, reproductive problems, and neurological disorders. The study highlights alarming data, with India, despite its relatively low pesticide consumption compared to other nations, facing serious environmental repercussions due to the use of chemicals. India is the fourth-largest producer of agrochemicals globally, and pesticides are applied to 25% of the country's cultivated land, with studies showing high pesticide residues in most food samples exceeding safe limits. India ranks fourth globally in agrochemical production, yet its pesticide consumption is significantly lower than other nations. With an average consumption of 0.5 kg per hectare, India lags behind Japan (12 kg/ha), Korea (6 kg/ha), and the USA (4.5 kg/ha). Despite being a major producer, India's share of global pesticide consumption is merely 3.57%, accounting for 2 million tons of pesticides produced annually. Furthermore, pesticides are applied to only 25% of the total cultivated land in India, covering approximately 16.7 million hectares. However, this limited usage has had substantial environmental repercussions. India has registered around 330 insecticide/pesticide molecules for use, with insecticides accounting for the highest consumption (65%), followed by herbicides and fungicides (Kashyap *et al.*, 2024).

State-wise Pesticide Consumption (in MT)

Source: Ministry of Agriculture & welfare, 2023-24



Over the past few years, regional laboratories, research institutions, scientific communities, and state agricultural universities with accredited labs have collected and analyzed samples from various markets, shops, and malls across different states. The findings are alarming: a significant majority of vegetables and fruits were found to contain high levels of pesticidal residues, exceeding the Maximum Residue Level (MRL). Furthermore, the presence of harmful contaminants

like Monosodium glutamate, Nickel, cobalt, chromium, Lead, Arsenic, Mercury, Manganese was also detected in these samples. These contaminants pose a serious health risk to consumers, underscoring the need for stricter regulations and enhanced monitoring to ensure food safety. Below are a few published glimpses

Metal in fruits and veg: How much is too much?



From soil and water into veggies: Heavy metals lace green produce

High Levels of Lead, Nickel in Veggies & Soil Around A'bad
 Parth Shah | parthshah@indianexpress.com
 Ahmedabad: The healthy serving of greens, leafy vegetables like spinach and cabbage considered central for good health might be laced with harmful heavy metals from the soil in which it's grown and the water it's fed.
 A doctoral study 'Heavy Metals in Soil, Agricultural Product and in Groundwater from Industrially Contaminated Zone of Gujarat' by Bhikuben Mohanty at School of

25% of fruit, veggies in Coimbatore unfit to eat



HEALTH, INT'L TRADE WILL BE HIT

Public policy expert D. Narasimha Reddy terms decision to raise in pesticide limits in spices as most unscientific.
 Earlier, maximum residue limit (MRL) was 0.01 mg/kg & now it has been raised to 0.1 mg/kg which is 10 times higher, he said.
 Central Insecticides Board and Registration Committee (CIBRC) does not do field trials of pesticides.

EFFECTS OF SYNTHETIC PESTICIDES



Danger in food basket

General health, respiratory, digestive, reproductive, endocrine, immunological and neurological.
 On women and children:
 • Reproductive problems such as infertility and miscarriages.
 • Learning and developmental problems.
 On ecosystem:
 • Pesticide drift harms non-target plants, livestock and wildlife.
 • Contaminates the soil and water.
 • Highly hazardous.

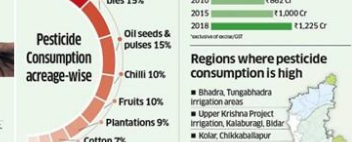
Two Class I pesticides used heavily in India and banned in other countries



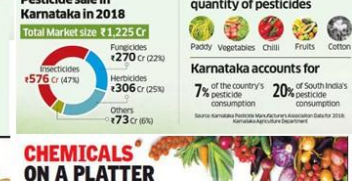
PESTICIDE RESIDUES ON VEGGIES

	Annul April 1st, 2015	Annul April 1st, 2016	Annul April 1st, 2017
Total samples taken	817	187	715
No residues	422	122	641
With pesticide residues	395	65	72
Non-approved pesticide residues	130	14	41
Above permissible limits of FSSAI	43	0	2
Samples with residue from APAC market	106	11	33
Samples from APAC with non-approved pesticide	66	10	28
APAC samples with residue above FSSAI limits	15	0	1
Farm vegetables with residue	88	4	8
Samples from farm veggies with non-approved pesticide	63	4	4
Farm vegetables with pesticide above FSSAI limits	28	0	1

Pesticide Consumption acreage-wise



Synthetic pesticide sale: Annual turnover in Karnataka



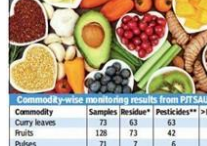
Regions where pesticide consumption is high



Crops that require high quantity of pesticides



WHAT THE BODY DOESN'T NEED



KEY TAKEAWAYS

At Prof Jayashanker Agri University, a total of 664 vegetable samples were collected from markets, farmers and organic outlets. The pesticides residues were found in 128 (25.2%) market samples, 41 (26.7%) farm samples and 21 (3.1%) organic samples.
 Out of 127 samples of spices tested at the university, 129 had pesticide residues and 18 exceeded maximum limits.

HEAVY METALS IN VEGETABLES



HEAVY METALS IN VEGETABLES

	Lead	Cadmium	Copper	Chromium	Iron	Max value found
Lead	25	8.4	42	44	44	42 (Cabbage)
Cadmium	56	44	44	44	44	44 (Brinjal)
Copper	38	8.9	8.9	8.9	8.9	8.9 (Tomato)

POISON PLATTER



PESTICIDE RESIDUES ON VEGGIES

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CHEMICALS ON A PLATTER



KIDS MOST VULNERABLE

Children are most vulnerable to intake of pesticide residue as their weight is less.
 Pesticide exposure through food chain causes a variety of diseases ranging from simple skin rashes and loose motions to digestive disorders, cancers and mental retardation.
 The body through nose (inhalation), skin (dermal contact) or ingestion.
 Pesticide exposure through food chain causes a variety of diseases ranging from simple skin rashes and loose motions to digestive disorders, cancers and mental retardation.
 Kids served three types of food for the study:
 First type included rice, mung & fried rice, upma.
 Second type had cooked vegetables such as eggplant, cabbage okra and fruits such as grapes.
 Third type had fruit juices, milk, and beverages.

Integrated Organic Farming with Modern Technology

To overcome the challenges/Impact of conventional farming, Integrated Organic Farming Systems (IOFS) provide a holistic approach that aims to enhance soil fertility, minimize environmental impact, and increase agricultural resilience. This system integrates diverse resources, including multi-crop approaches, livestock, and agroforestry practices, to promote sustainable agriculture. These methods not only restore soil health but also ensure long-term crop productivity without harming the environment.

The nutrient management system in organic farming relies on organic manures, compost, biofertilizers, and natural amendments such as vermicompost and rock phosphate to maintain soil health and fertility. This system leverages natural resources to create a balanced and sustainable ecosystem, mitigating the need for synthetic fertilizers and pesticides.

Pest and Disease Management in Organic Farming

Pest and disease management is a critical aspect of organic farming, which requires a multi-step, eco-friendly approach. Organic farming avoids chemical pesticides and instead focuses on prevention, monitoring, and timely intervention. Techniques such as crop rotation, sanitation, and the use of biopesticides (e.g., neem oil, garlic extract) are employed to control pests. These natural methods reduce environmental impact while ensuring the health and safety of both crops and consumers.

Zero Waste: Promoting Sustainability

A key principle of organic farming is the "zero waste" concept, which emphasizes recycling waste products from one process to benefit others. Animal waste, weeds, and crop residues are recycled into the system as nutrients, reducing waste and contributing to the sustainability of the farming ecosystem. This approach aligns with the broader goal of minimizing the environmental footprint of agriculture and creating a circular, self-sustaining agricultural system.

Adopting Organic Food Habits for a Sustainable Future

Choosing organic food is not only beneficial for health but also plays a crucial role in creating a sustainable future. Organic food options are free from harmful chemicals and pesticides, offering a safer alternative for consumers. Furthermore, organic foods generally have higher nutritional value than conventionally grown produce, which can reduce the risk of chronic diseases like heart disease, diabetes, and obesity. By prioritizing organic food choices, individuals can help foster a healthier lifestyle and contribute to the broader goal of sustainability.

Making Informed Food Choices

To promote organic food habits, individuals can make conscious food choices:

- **Prioritize Organic Produce:** Choose organic fruits, vegetables, grains, and dairy products that are free from chemicals.
- **Support Local Farmers:** Purchase organic produce directly from local organic farmers to support sustainable agricultural practices.
- **Grow Your Own:** Cultivate fruits and vegetables at home, in a terrace garden or backyard, to ensure access to chemical-free food.

Additionally, adopting food safety practices, such as mindful food storage, handling, and preparation, can further minimize exposure to harmful chemicals.

Conclusion

The transition to organic farming and food habits is crucial for a healthier and more sustainable future. Organic farming offers an environmentally friendly and restoring soil health, preserving biodiversity, and providing healthier food options. By adopting organic food habits, individuals can reduce exposure to harmful chemicals and promote a more sustainable, eco-friendly lifestyle.

Encouraging future generations to embrace organic farming and food habits will not only improve their health but also contribute to a more sustainable and sustainable planet. As we make more informed choices about the food we consume, we can help preserve the environment and ensure a healthier future for generations to come. The adoption of organic farming is not just a trend but a necessary step towards a sustainable, chemical-free future.

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ONE DISTRICT ONE PRODUCT (ODOP): EXTENSION STRATEGIES FOR LOCALIZATION

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Abstract

Promoting distinctive, district-specific products is the goal of the government-led One District One Product (ODOP) program, which aims to increase local business and rural livelihoods. ODOP assists in converting traditional skills into revenue-generating businesses by emphasizing value addition, branding, and market access. In order to increase the implementation of ODOP, this paper addresses the role of localized extension techniques, including training, technology diffusion, participatory planning, and convergence with development schemes. In order for farmers, SHGs, and FPOs to fully benefit from this program and become competitive market players, effective extension support is necessary.

Key words: ODOP, Extension strategies, Local entrepreneurship, Market linkages.

Introduction

India is a culturally diverse country with a vast array of agricultural and related products. Whether it's a handicraft, a cattle breed, a processed dish, or a traditional crop, each district has something special to offer. The Government of India recognized this unrealized potential and, as part of the PM Formalization of Micro Food Processing Enterprises (PMFME) project, established the One District One Product (ODOP) initiative. Promoting district-native goods, assisting with value addition, branding, and marketing, and eventually raising local communities' standard of living are the goals. Extension services, which serve as a link between the field and knowledge, are essential to the success of this endeavour. Localization of ODOP through extension is the key to making the program farmer- and enterprise-friendly.

The Essence of ODOP

1. Identify a district's most prominent product or enterprise.
2. Encourage its growth through market connections, technical training, processing, packaging, and branding.
3. Encourage local businesses and job opportunities.
4. Assure the formalization and support of small and micro-enterprises in the food industry.

Few examples of ODOPs include:

1. Chittoor (AP): Mango pulp and processing
2. Pudukkottai (TN): Groundnut-based products
3. Solapur (MH): Pomegranate
4. Barabanki (UP): Mentha oil and products
5. Warangal (TS): Chilli

Why Localization Matters?

Localization means aligning extension strategies with the specific context, traditions, resources, and challenges of the district and its people. A mango-based processing unit in Chittoor cannot function

on the same blueprint as a turmeric enterprise in Erode. Hence, tailored extension services are essential to ensure local adoption and sustainability.

Extension Strategies for ODOP Localization

1. Participatory Product Identification

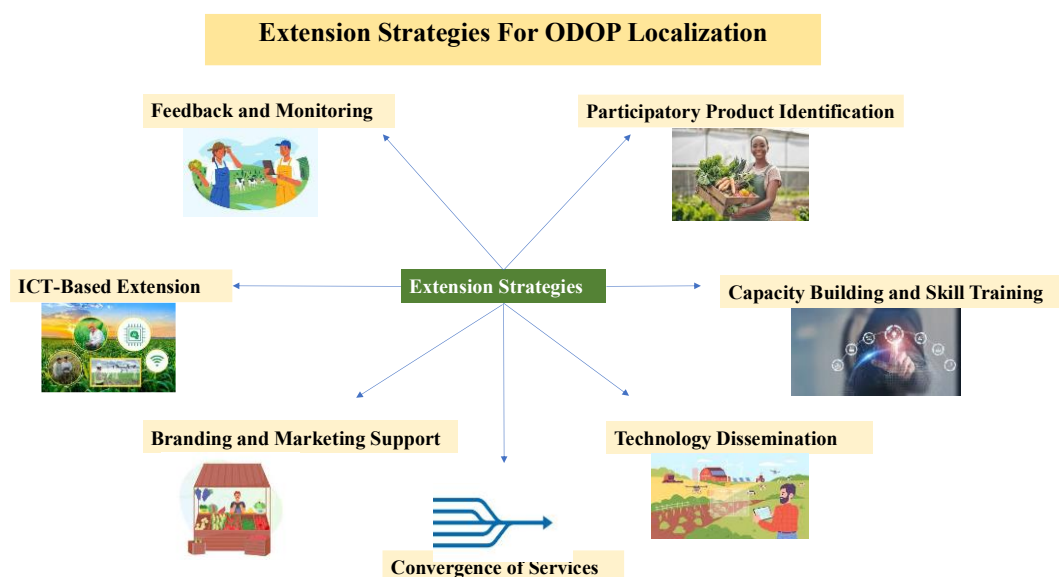
Involve farmers, SHGs, FPOs, artisans, and local entrepreneurs in identifying the most promising ODOP. Use tools like village mapping, resource analysis, and market studies to make informed decisions. Recognize traditional knowledge and local pride associated with certain crops or products.

2. Capacity Building and Skill Training

Organize on-site and hands-on training in production, processing, grading, storage, and packaging of the selected product. Collaborate with KVKs, ITIs, polytechnics, and NGOs to deliver targeted training. Promote exposure visits to successful ODOP enterprises in other districts.

3. Technology Dissemination

Popularize low-cost, appropriate technologies for small processors, such as solar dryers, small-scale milling units, cold storage units, etc. Create easy-to-use technical manuals and visual guides in local languages. Conduct demonstrations and field days for farmers and entrepreneurs.



4. Convergence of Services

Link ODOP efforts with schemes like PMFME, PMKSY, DAY-NRLM, and RSETIs. Coordinate with bankers and NABARD for credit linkages and subsidies.

5. Branding and Marketing Support

Guide entrepreneurs on local branding, packaging, and geographical indication (GI) tagging. Promote collective marketing through FPOs, cooperatives, and e-commerce. Organize district-level fairs and buyer-seller meets to expand market reach.

6. ICT-Based Extension

Use WhatsApp groups, YouTube videos, community radio, and mobile apps to disseminate information on quality standards, prices, schemes, and training. Develop local success stories into

audio-visual content to inspire peer learning. Create district-level ODOP portals with inputs from extension agencies.

7. Feedback and Monitoring

Establish a local extension team to assess progress, constraints, and capacity gaps regularly. Facilitate interactive meetings with producers to understand real-time needs. Incorporate farmer feedback into program design and training schedules.

Case study on ODOP

Andhra Pradesh's Anantapur district chose groundnuts as its One District One Product (ODOP). Extension organizations were crucial in helping SHG women by teaching them how to make chikki, roast, and extract oil. By means of convergence with the PMFME scheme, processing activities were supported by small-scale machinery. After local FPOs assisted with branding and packaging, the products were marketed locally and sold in weekly markets and online. Particularly for women and young people living in rural areas, this example demonstrates how localized extension strategies can successfully encourage entrepreneurship and create revenue.

Challenges in Localization

1. Lack of awareness among small producers.
2. Inadequate infrastructure and credit support.
3. Weak market linkages and branding capacity.
4. Need for multi-stakeholder coordination.

Conclusion

The One District One Product program has the potential to revolutionize rural economies, but its effectiveness hinges on how effectively it is implemented locally. By creating and providing integrated, need-based, and participatory extension services, we can make sure that ODOP develops into a movement of people rather than merely a policy. The foundation of the ODOP ecosystem must be district-level extension teams going forward, enabling communities to capitalize on their unique assets and transform them into sustainable sources of income.

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POSTHARVEST TECHNOLOGY APPLICATION OF NANOTECHNOLOGY IN POSTHARVEST MANAGEMENT OF HORTICULTURAL CROPS

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Introduction

The use of nanotechnology is becoming more widespread in all scientific domains, including agriculture and health. In order to minimize postharvest diseases of fruits and vegetables at the scientific and industry levels, different properties of nanomaterials and nanoparticles are also being effectively applied to change our farming into a sustainable horticulture in particular and a sustainable agriculture in general (Feregrino-Perez *et al.*, 2018). Good agricultural or cultural practices and locations are the primary determinants of postharvest production, which varies from 30% to 50% (Ladaniya *et al.*, 2008). Minimizing the losses will ultimately increase their supply and reduce the overall cost. There are some advancing applications of nanotechnology in the field of post harvest management of horticultural crops and they are summarized below.

A. Silver Nanoparticle for Increasing Vase Life of Cut Flowers

Vase life and quality are important considerations when using cut flowers for a variety of events. Microbial growth that prevents water uptake limits its shelf life. Nanomaterials, such as Nano-silver, have antibacterial and ethylene-inhibiting properties. In addition to inhibiting bacterial development, silver nanoparticles also increase solution uptake and prolong vase life by penetrating stem tissues, lowering ethylene synthesis, and suppressing ethylene-related genes ACO1 and ACS1 (Bahremand *et al.*, 2014). These nanoparticles have no negative effects and are extensively used, stable, safe, and simple to apply (Bahremand *et al.*, 2014).

B. Applications of Nanotechnology in Aromatics and Spices Industries

Spices improve taste, color, and shelf life by preventing bacterial growth, making them perfect for flavoring food. *Aspergillus flavus* and *Aspergillus parasiticus* create mycotoxins called aflatoxins, which can stunt growth, erode immunity, and result in liver cancer. Aflatoxin B, G, and M1 have been identified using a gold NPs-antibody label system (Anfossi *et al.*, 2013). Spice quality is improved by nanocoatings with metallic nanoparticles or biopolymers, which increase color, flavor, antioxidant content, and shelf life. Using NPs such as Nano SiO₂, Nano Ca₂SO₄ Si, Nano sodium aluminosilicate, and dicalcium phosphate, nanotechnology also reduces spice lumping, increasing flowability and market value (Greiner *et al.*, 2009).

C. Nanotechnology for Packaging

New fruit packaging could be created by nanotechnology. By mixing polyethylene with nanopowder (nano-Ag, kaolin, anatase TiO₂, mineral TiO₂), the new technology of nano-packing materials with decreased relative humidity, oxygen transmission rate, and high strength was created, and it improved the fruits' ability to be preserved at 40°C during storage (Sujithra, S *et al.*, 2019) When compared to traditional packing (polyethene bags), strawberry fruits' sensory attributes, chemical composition, and physiological characteristics can be better preserved by nano-packaging (Yang *et*

al., 2010) Additionally, nano packaging reduces the pace of degradation and the levels of anthocyanin and malondialdehyde more effectively than conventional polyethene packing. Packaging of spices is a complex issue as the technique should not only enhance shelf life but also retain its aroma, colour, flavour and reduce infection of microbes. Electrochemical anodisation was used to produce cylindrical nanopores between 15 and 100 nm diameter on an aluminium surface of packaging foil. These surfaces were then incubated with cultures of *E. coli* and *Listeria innocua*. The surfaces covered with nanopores of 15–25 nm diameter significantly inhibited both attachment and biofilm formation which are safe for spices packaging (Zhang, X *et al.*, 2017)

D. Nanoemulsions

A mixture of two or more difficult-to-mix liquids is called an emulsion. Nanoemulsions, which fall within the nanoscale emulsion range, are produced to enhance the delivery of active medicinal components. These are the isotropic, thermodynamically stable systems when two immiscible liquids are combined with an emulsifying agent, such as a surfactant or co-surfactant, to create a single phase. Using Nanoemulsion coating of Carnuba wax of 42 nm diameter (also called Brazil wax and palm wax) is an accepted proposition. This wax was extracted from leaves of the carnauba palm (*Copernicia prunifera*) at 2.4% and it was applied on Papaya fruit. The fruits were stored for 9 days at 22°C and a relative humidity of 60%–70%; it was found that the fruits showed a reduced decaying and loss of mass (Rhim, J W 2004) Nanolaminate is a very thin food-grade material with chemically or physically bonded dimensions that spans from 1 to 100 nm/layer (Ravichandran R 2010) When making edible films, nanolaminate offers numerous benefits. Many horticultural products, as well as chocolate, toffees, baked foods, and French fries, contain edible films (Zambrano Zaragoza *et al.*, 2014) Foods are shielded by these layers against gas, lipid, and moisture loss. These films preserve the fruits' color, flavor, antioxidant content, and nutritional value while also enhancing their textural qualities.

E. Multiple Chips (Nanobiosensors) for Labelling of the Products

Recently, food products have made extensive use of nanotechnology-based biodegradable sensors in the form of tiny chips, such as electronic tongue technology sensors. When the product's pH fluctuates due to spoiling, its color changes. The preservative packing is controlled by a "Release on command" nanobioswitch (Netherlands) (Yadollahi, A *et al.*, 2009) Food nanostructures that function as biosensors use biological substances such as proteins or carbohydrates (Imafidon, G. I *et al.*, 2009). These biosensors serve as both a tool for food product tracing and a detector of food pathogens and other microorganisms. Nanotechnology is also useful in encapsulation systems for protection against environmental factors. Further, it can be used in the design of food ingredients such as flavour and antioxidants (Haruyama, T 2003). The main objective is to improve the functionality of such ingredients while minimizing their concentration. As the infusion of these innovative ingredients gets into foods, it gains more popularity (Lawrence *et al.*, 2000) It will also occur the greater exploration of delivery controlled release systems for nutraceuticals (Delfino *et al.*, 2020) Based on nanomaterials used in diverse food and agriculture industries, different biosensors are employed. Applications for nano-biosensors are numerous and include the detection of food-borne poisons utilizing multifunctional nanoparticles and the recognition of viruses employing antibody sensor arrays on self-assembled nanoscale block copolymer patterns. Additionally, it is employed in the detection of pore-forming poisons and molecularly imprinted polymers for the identification of viruses in plants and insects.

Conclusion

Nanomaterials have significant potential in postharvest technology by reducing losses and preserving the quality of horticultural crops. Practices like early harvest, washing, and proper handling are key, and affordable nano-edible coatings—especially those with zinc and silver—help delay spoilage and prevent microbial attacks. These technologies can improve market value for farmers. However, more research is needed on nano-packaging systems to ensure safety and effectiveness. While nanotechnology benefits agriculture, medicine, and the environment, it may also pose health and ecological risks. Therefore, thorough investigation is essential before widespread application.

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MULTIPLE REGRESSION ANALYSIS USING MS EXCEL: A STEP-BY-STEP GUIDE

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Abstract

Multiple regression analysis is a fundamental statistical technique used to explore the relationship between one dependent variable and more than one independent variables. This paper demonstrates the step-by-step execution of multiple regression using Microsoft Excel software. It helps in many fields, particularly in fisheries science, including fish yield prediction, water quality assessment, environmental impact modeling, and socioeconomic analysis.

Keywords: Multiple Regression Analysis, Microsoft Excel, Variables, Fisheries Science and Data Analysis Tool Pak

Introduction

Regression is the basic tool for all statistical analysis. It means what is the precise form of the relationship between two variable prediction of one variable based on another in the form of an equation. It will determine accuracy of the model and provides predicting values for dependent variable. Multiple regression analysis is a widely used statistical technique for understanding and predicting outcomes influenced by several factors. It plays a crucial role in fields such as environmental science, biology, economics, and fisheries, where multiple variables interact to affect a single outcome. In Excel's Data Analysis Tool Pak simplifies the process, making it easier for researchers to apply regression methods in real-world scenarios.

Multiple Regression Model

Multiple regression analysis examines the relationship between one dependent variable and two or more independent variables. It helps estimate how each predictor influences the outcome, while controlling for the effects of other variables.

$$Y = a + b_1 x_1 + b_2 x_2 + \dots + b_n x_n + e$$

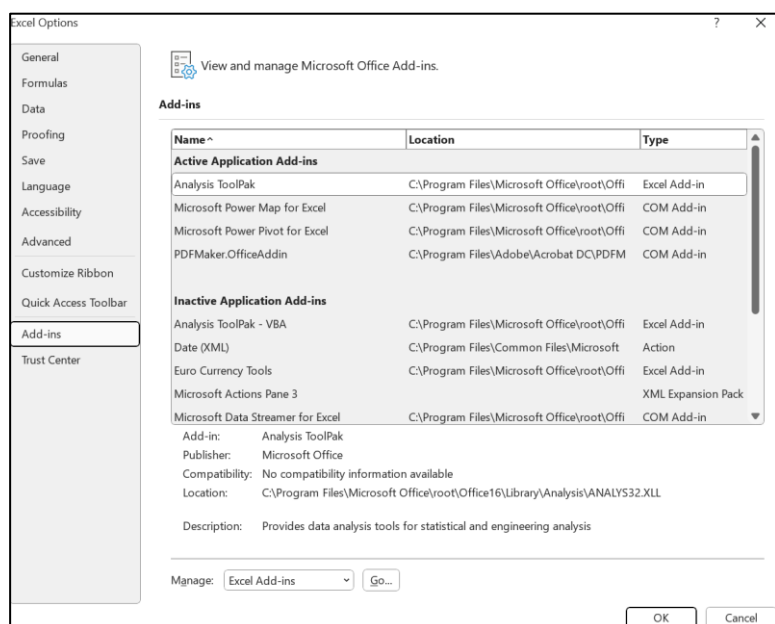
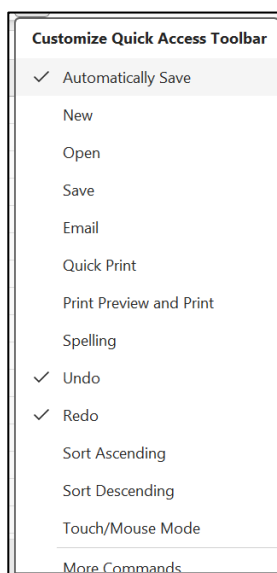
Where,

$Y \rightarrow$ is the value of the dependent variable, which is being predicted or explained

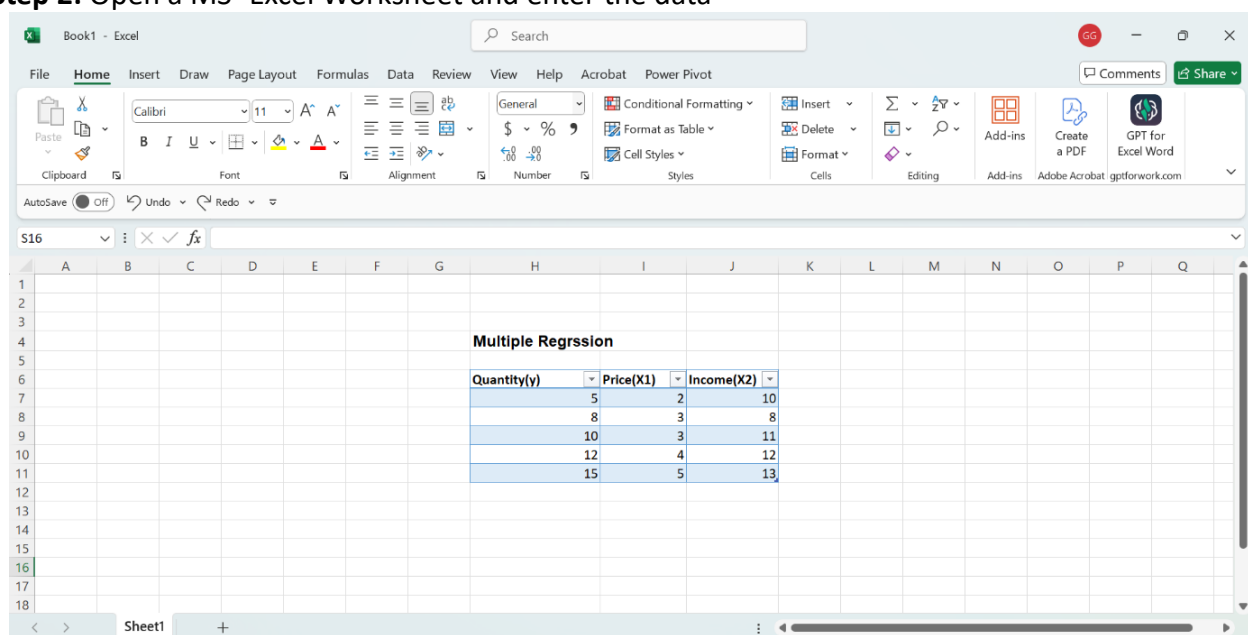
- $a \rightarrow$ is a constant or intercept on Y axis
 $b_1 \rightarrow$ is the regression coefficient for X_1 and indicates the change in Y for one unit change in X_1 , controlling for $X_2, X_3, \dots$
 $X_1 \rightarrow$ First independent variable that is explaining the variance in Y.
 $b_2 \rightarrow$ is the regression coefficient for X_2 and indicates the change in Y for one unit change in X_2 , controlling for $X_1, X_2, X_3, \dots$
 $X_2 \rightarrow$ Second independent variable that is explaining the variance in Y and so on.

Steps in MS Excel

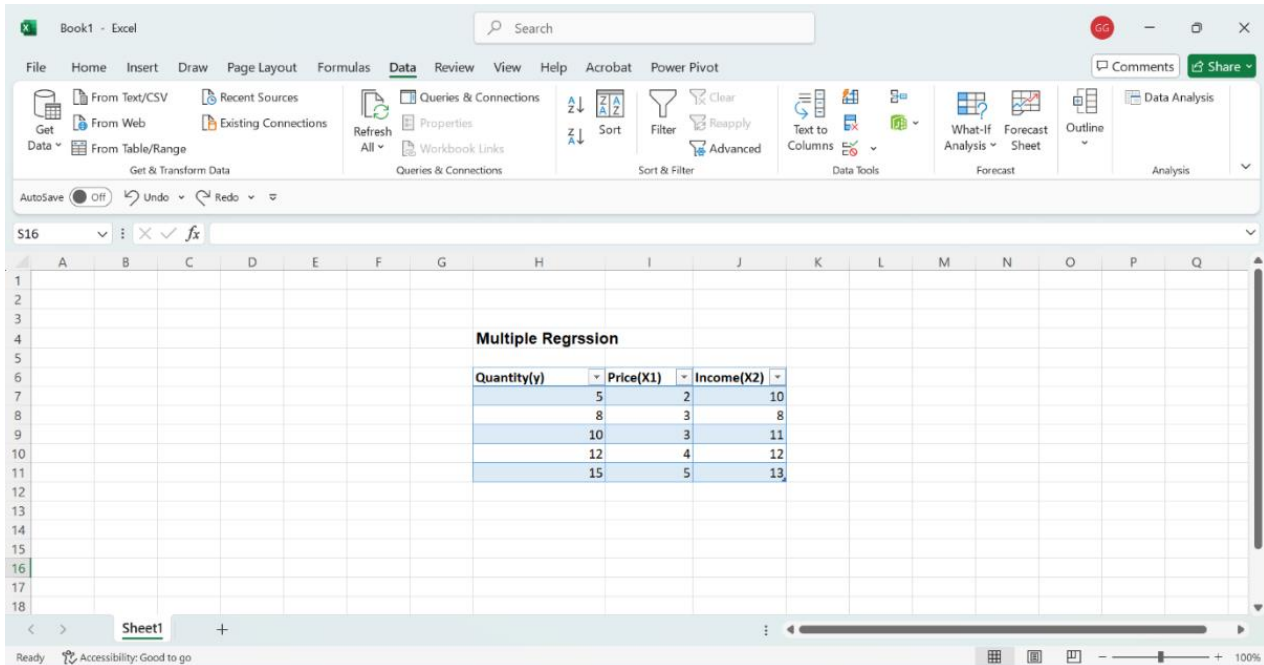
Step 1: Enable Data Analysis Tool Pak in MS Excel



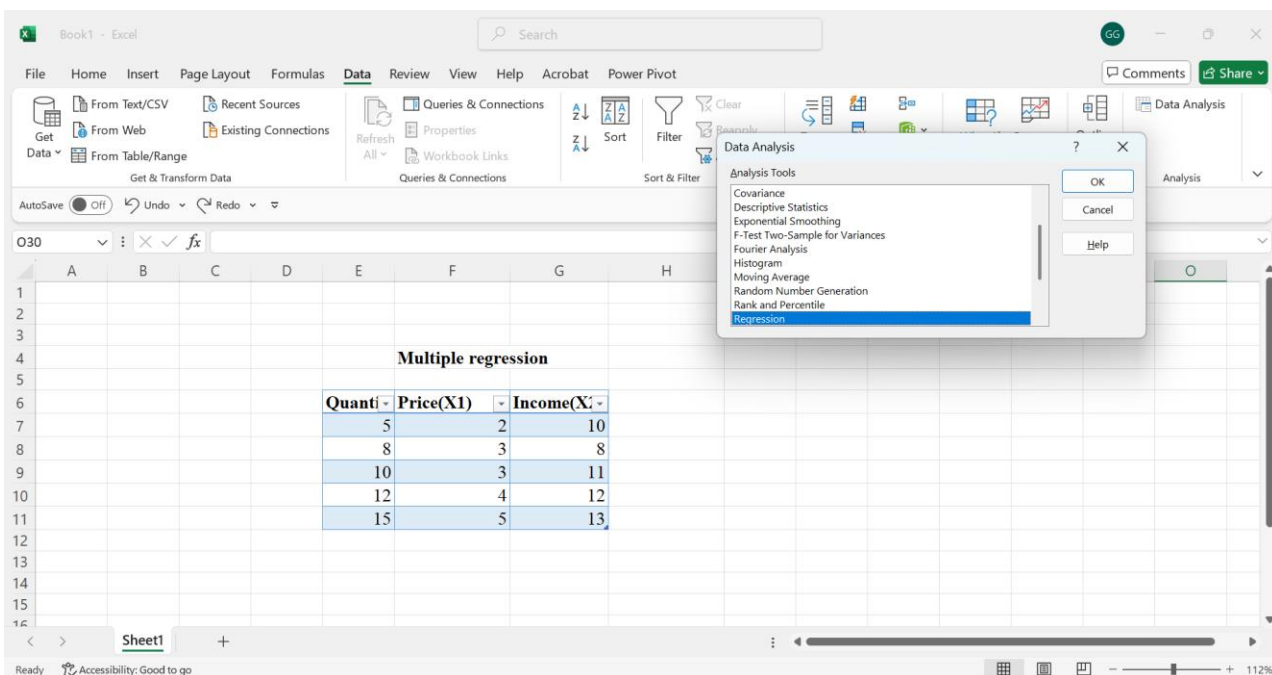
Step 2: Open a MS- Excel Worksheet and enter the data



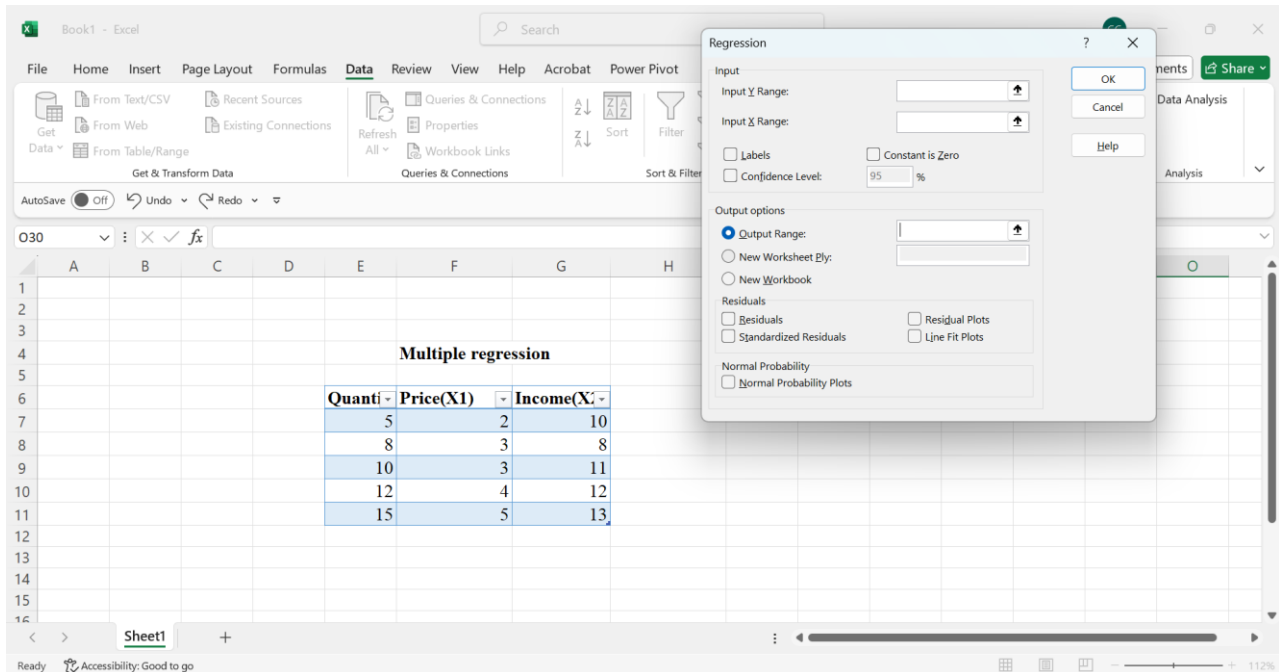
Step 3: Go to Data tab and select Data Analysis



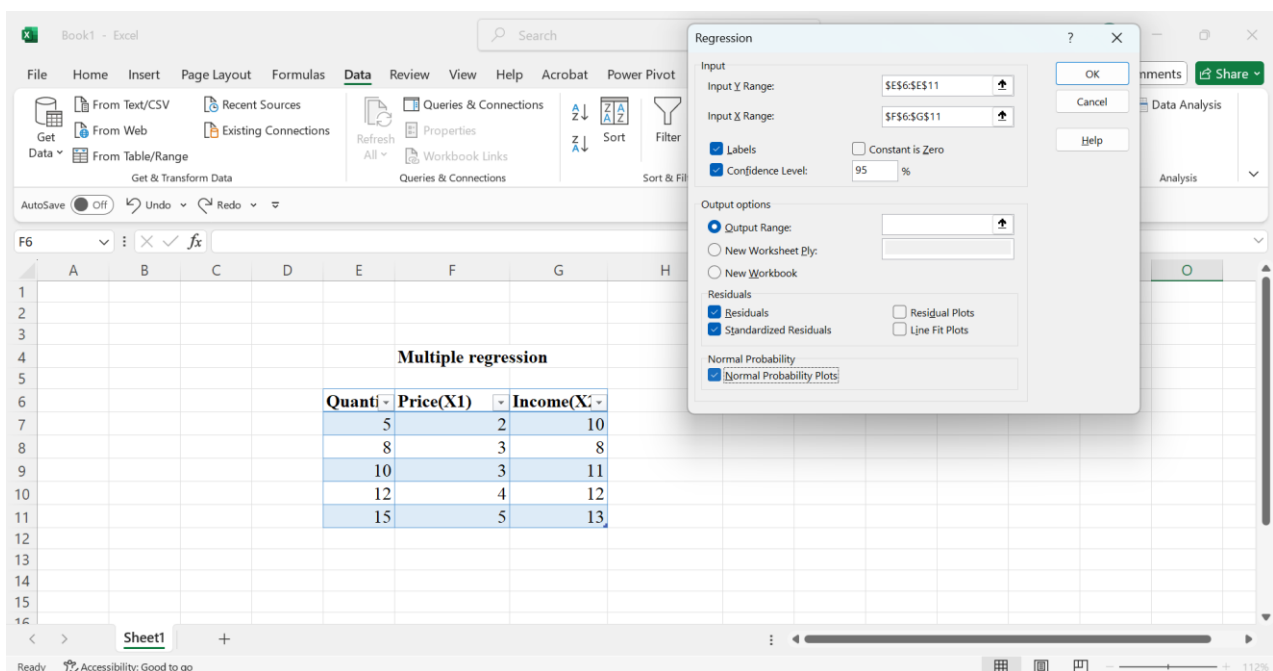
Step 4: Choose Regression from the list of analysis tools



Step 5: The Regression Analysis dialog box will appear



Step 6: Select the input data ranges for the dependent variable (Y) and independent variables (X₁, X₂).



Step 7: Choose the output range where the regression summary table should be displayed.

The screenshot shows the Excel interface with the 'Data' tab selected. A 'Regression' dialog box is open, showing the following settings:

- Input Y Range: \$E\$6:\$E\$11
- Input X Range: \$F\$6:\$G\$11
- Labels: ☒ (checked)
- Confidence Level: 95 %
- Constant is Zero: ☐ (unchecked)
- Output options: ☒ Output Range: \$I\$10 (selected), ☐ New Worksheet Ply: (unchecked), ☐ New Workbook: (unchecked)
- Residuals: ☒ Residuals, ☒ Standardized Residuals, ☐ Residual Plots, ☐ Line Fit Plots
- Normal Probability: ☒ Normal Probability Plots

The data table in the background is as follows:

Quantity	Price(X1)	Income(X2)
5	2	10
8	3	8
10	3	11
12	4	12
15	5	13

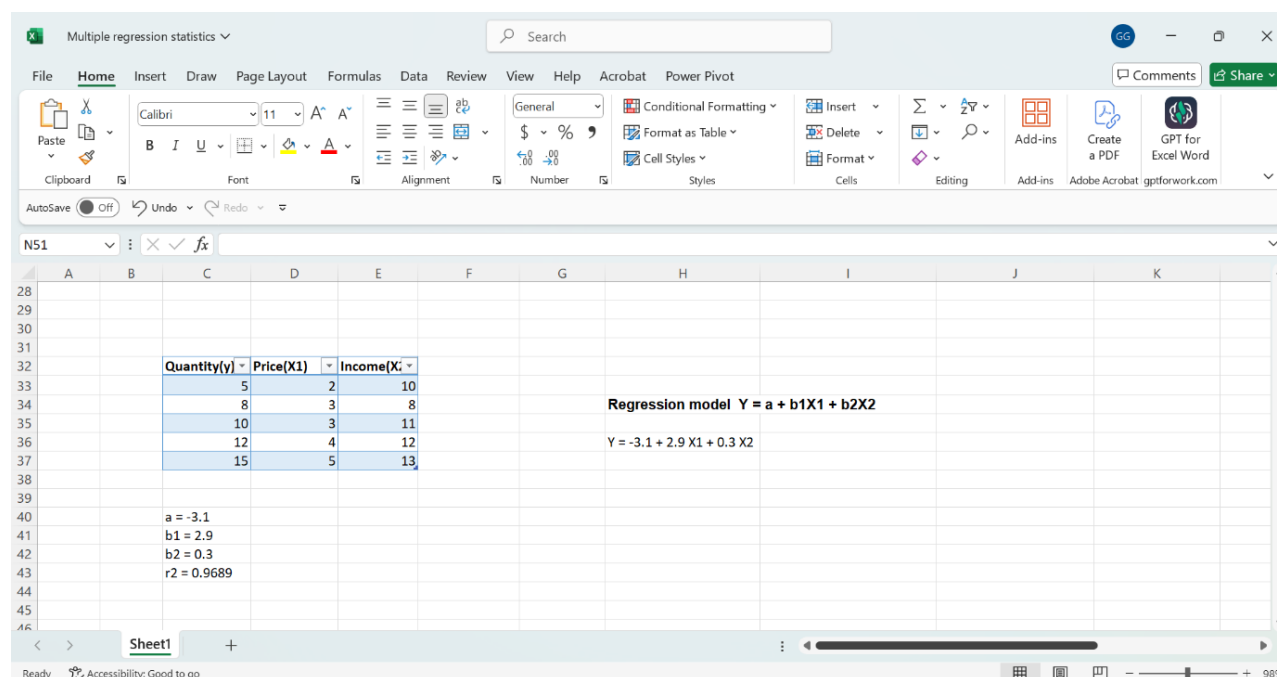
Step 8: Summary output table will be generated, showing the multiple regression statistics.

The screenshot shows the Excel interface with the 'Home' tab selected. The 'Multiple Regression SUMMARY OUTPUT' table is displayed, showing the following statistics:

Multiple Regression			SUMMARY OUTPUT							
Quantity(y)	Price(X1)	Income(X2)	Regression Statistics			ANOVA				
5	2	10	Multiple R	0.984360461		df	SS	MS	F	Significance F
8	3	8	R Square	0.968965517	Regression	2	56.2	28.1	31.22222	0.031034
10	3	11	Adjusted R Square	0.937931034	Residual	2	1.8	0.9		
12	4	12	Standard Error	0.948683298	Total	4	58			
15	5	13	Observations	5						

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-3.1	2.805352028	-1.10503	0.384294955	-15.17045556	8.97045556	-15.1704556	8.97045556
Price(X1)	2.9	0.608276253	4.767571	0.041289573	0.282798519	5.517201481	0.282798519	5.517201481
Income(X2)	0.3	0.360555128	0.83205	0.492907447	-1.251343504	1.851343504	-1.2513435	1.851343504

Step 9: Fit that values in Multiple Regression Model.



Applications of Multiple Regression in Fisheries

- **Aquaculture Optimization** - To evaluate the impact of feed composition, stocking density, and management practices on growth and production.
- **Fish Yield Prediction** - Used to estimate fish production based on environmental parameters like temperature, salinity, dissolved oxygen, and nutrient levels.
- **Water Quality Assessment** - Analyses the combined effect of multiple water quality indicators on fish health and survival rates.
- **Fish Disease Modeling** - Evaluating the role of multiple environmental variables in the outbreak of diseases in aquaculture systems.
- **Climate Change Impact Assessment** - Estimating how variables like rainfall, temperature, and river discharge affect fisheries yield over time.
- **Stock Assessment** - Assists in modeling fish population dynamics by relating recruitment or biomass to ecological and fishing pressure variables.
- **Bycatch Prediction** - Using multiple regression to model bycatch composition based on mesh size, trawl duration, depth, and time of day.
- **Length-Weight Relationship Studies** - Though traditionally handled with simple regression, multiple regression can be used when incorporating multiple predictors (e.g., age, sex, season).
- **Socioeconomic Analysis**: Used in evaluating the impact of various livelihood, market, and policy factors on fisher incomes and community resilience.

Conclusion

Multiple regression analysis in MS Excel provides a user-friendly and efficient method for exploring complex relationships in fisheries science. It enables data driven decision making, supporting sustainable management and predictive modeling in aquatic resource research.

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MOBILE APPS HELPING FARMERS GROW BETTER VEGGIES

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Abstract

The use of mobile apps in Indian vegetable farming is changing the game for agricultural practices, particularly for small-scale farmers. These applications provide important real-time updates on weather, help diagnose pests and diseases, track market trends, and offer expert advice, which in turn greatly enhances crop yield and farmer earnings. Tools such as Plantix, Krish-e, and Kisan Suvidha give farmers tailored, practical insights that improve how they use their resources and encourage eco-friendly methods. Although there are challenges related to digital skills and access to connectivity, the ongoing growth of mobile technology holds the potential to reshape the future of vegetable farming in India.

Keywords: Digital transformation, Mobile apps, Pest management, Sustainable agriculture
Vegetable farming

Introduction

Vegetable farming stands as a crucial foundation of agriculture in India, providing livelihoods for millions and feeding a population that surpasses 1.4 billion people. Among the agricultural workforce, smallholder farmers account for a significant 86%. However, these farmers face numerous hurdles, including erratic weather patterns, pest problems, and limited access to modern farming techniques. In recent times, the rise of mobile applications has initiated a digital transformation, giving farmers access to innovative tools that boost vegetable production. These apps offer essential features like real-time weather updates, effective pest management strategies, market trends, and expert guidance, all of which empower farmers to cultivate healthier crops such as tomatoes, onions, and spinach.

The Need for Digital Solutions in Vegetable Farming

Indian vegetable farmers face a multitude of challenges. With climate change causing unpredictable monsoons and extreme heat, the 2023 floods in Punjab led to a 15% drop in tomato production. Additionally, pest and disease outbreaks, such as the whitefly invasion affecting brinjal crops in Maharashtra, can result in yield losses of up to 20%.

Many smallholder farmers struggle to access crucial information about market prices, quality seeds, and sustainable farming methods. According to the World Bank, agricultural productivity in India lags 35-50% behind global standards, largely due to slow adoption of technology. Nonetheless, a 2020 Boston Consulting Group study revealed that 48% of rural households own smartphones, which allows mobile apps to provide valuable, localized insights that help bridge these information gaps.

Crucial Mobile Apps Transforming Vegetable Farming

A variety of mobile applications are revolutionizing the way Indian vegetable farmers operate by tackling their unique challenges. Here are eight notable examples:

Kisan Suvidha

Kisan Suvidha, launched in 2016 by the Ministry of Agriculture, serves as a valuable resource for farmers, offering weather updates, market prices, and crop guidance in ten different Indian languages. For those growing vegetables, it includes tailored sowing schedules for crops like cabbage, along with essential pest control advice. With over a million downloads, this app has been particularly beneficial for farmers in Uttar Pradesh, enabling them to plan their irrigation based on five-day weather predictions. This approach has notably reduced water wastage by 25% in 2024.

**Pusa Krishi**

Pusa Krishi, developed by the Indian Agricultural Research Institute (IARI) in the same year, focuses on providing insights into high-yield vegetable varieties, including the Pusa Hybrid-4 tomatoes, and offers efficient farming techniques. Through video tutorials, it teaches farmers in Haryana about drip irrigation methods for eggplants, resulting in a 30% decrease in water usage. Furthermore, the app connects farmers with ICAR experts who provide guidance on managing diseases, which has led to a 12% increase in cauliflower yields in 2024.

**Plantix**

Plantix is revolutionizing the way farmers diagnose diseases in vegetable crops through its AI-powered image recognition technology. By simply uploading photos of their affected plants, farmers receive immediate solutions for various issues, such as powdery mildew on cucumbers. In Nashik, this innovative tool enabled farmers to spot fungal infections in onions early on, which saved them from a staggering 25% loss in yield in 2024. Moreover, Plantix's pest monitoring alerts are proving invaluable for farmers in Gujarat, as they help track local outbreaks effectively.

**Krish-e**

Krish-e, launched by Mahindra Mahindra. This platform provides tailored crop calendars for vegetables, including spinach and capsicum, in eight different languages. In 2023, Krish-e's pest management features enabled farmers in Andhra Pradesh to cut down their pesticide usage by 20%, while simultaneously boosting tomato yields by 15%. The app also incorporates weather data to facilitate precise planting, thereby improving efficiency for smallholders in Telangana.

**AgriApp**

AgriApp is another essential tool for farmers, offering extensive guidelines on vegetable cultivation—covering everything from soil needs to harvesting techniques. Its chat function connects farmers in Tamil Nadu with experts, allowing them to seek advice on issues like leaf spot in leafy greens. With a commendable rating of 4.3 out of 5 and over 10,000 downloads, AgriApp's video-based resources on organic farming have encouraged farmers in Kerala to adopt more sustainable methods for cultivating bitter melon.



Arka Bagwani

Developed by ICAR-IIHR in Bengaluru, Arka Bagwani is focused on horticulture, providing in-depth guides on vegetable crops such as cherry tomatoes. Available in English, Hindi, and Kannada, this app has assisted farmers in Karnataka in enhancing their yields by 10% through optimized fertilizer schedules in 2024. Additionally, it connects farmers with online marketplaces for direct sales.

**Meghdoot**

Lastly, Meghdoot is a collaborative effort involving the India Meteorological Department, IITM, and ICAR, designed to offer weather-based agricultural advice in 11 Indian languages. Updated every week, it provides crop-specific recommendations for vegetables like okra. In 2024, Meghdoot played a crucial role in helping farmers in Bihar protect their bean crops from unexpected rains, resulting in a 20% reduction in losses.

**Meghdoot****Bharat Krushi Seva**

Bharat Krushi Seva is revolutionizing farming by using IoT technology to provide real-time irrigation alerts. This innovation has helped okra farmers in Chennai cut their water usage by 30% in 2024. Along with irrigation support, it also gives farmers valuable crop care advice, updates on market trends, and a platform to connect with each other and share their experiences. In Rajasthan, the initiative's emphasis on sustainable farming practices has encouraged farmers to switch to organic methods for growing peas, resulting in a 25% reduction in chemical usage.

**How Apps Enhance Vegetable Farming**

Mobile apps provide farmers with essential tools tailored to meet their specific needs.

Real-Time Weather and Market Insights

Apps like Kisan Suvidha and Meghdoot are changing the way farmers access weather forecasts and market prices, offering hyperlocal insights. For instance, in 2024, a farmer in Bihar leveraged Kisan Suvidha to sell his potatoes at prices that were 10% higher by strategically timing his sales to coincide with peak demand. Additionally, the timely weather alerts provided by these apps play a crucial role in safeguarding crops, such as beans, from unexpected rains, effectively reducing potential losses.

Pest and Disease Management

Apps powered by AI, such as Plantix and Krish-e Nidaan, offer instant disease diagnosis for crops. In Rajasthan, Plantix played a crucial role by sending alerts about aphids, which helped save 30% of the pea harvest in 2023. These applications not only assist farmers in quickly identifying issues but also help reduce the dependency on pesticides. This shift supports more sustainable farming practices, especially for crops like cabbage.

Access to Expert Advice

Pusa Krishi and AgriApp play a vital role in connecting farmers with agricultural scientists. In 2024, a farmer from Maharashtra tackled a tomato blight problem using AgriApp's chat feature, resulting in a 12% boost in yields. This innovative approach helps to close the knowledge gap for small-scale farmers who often struggle to access extension services.

Sustainable Practices and Resource Efficiency

Applications such as Bharat Krushi Seva and Arka Bagwani are paving the way for organic farming and smarter resource management. In 2024, Kheti Badi provided valuable tips on natural pest control, leading farmers in Gujarat to cut down their chemical usage in cabbage fields by an impressive 25%. Moreover, the integration of IoT technology in Bharat Krushi Seva is streamlining irrigation processes, which significantly boosts resource efficiency.

Economic and Social Impacts

Mobile apps are making a significant economic impact by boosting yields and incomes for farmers. According to a 2023 NABARD study, farmers using apps like Krish-e saw their vegetable yields increase by 10–15%, which translated to an annual income boost of around 3–5 lakh for a farm of just 1 acre. Additionally, platforms such as eNAM and Arka Bagwani provide farmers in Chennai with direct access to markets. This helps eliminate middlemen and has resulted in profit increases of about 20% for these vegetable growers.

Challenges and the Way Forward

However, despite these advantages, mobile apps are encountering several hurdles in terms of adoption. In rural areas, limited internet access is a major barrier, with only 48% of households connected. Digital literacy is another challenge, particularly among older farmers in states like Bihar. Moreover, many apps often lack substantial content focused on vegetables or fail to support regional languages like Odia.

To tackle these issues, government initiatives such as Digital India are crucial for improving connectivity. Subsidies under PM-KUSUM can make smartphones more affordable for farmers. Additionally, training programs launched by ICAR and state universities can work to enhance digital literacy. Creating more vegetable-focused apps in various languages will also help drive greater adoption.

Conclusion

In conclusion, mobile applications are transforming vegetable farming in India by providing timely and localized solutions to age-old issues. Tools like Plantix, which offers AI diagnostics, and Meghdoot, with its weather alerts, are empowering farmers to cultivate healthier vegetables, boost their yields, and improve their earnings. As India continues to enhance its digital infrastructure, these apps will become increasingly essential for making vegetable farming not only sustainable but also lucrative. By tackling challenges related to connectivity, literacy, and the availability of content, mobile apps can help ensure that Indian farmers not only survive but thrive, contributing to food security and rural prosperity.

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MINIMUM LEGAL SIZE (MLS) FOR FINFISH IN ANDHRA PRADESH: A KEY TO SUSTAINABLE FISHERIES

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Andhra Pradesh is a prominent state in India regarding marine fisheries, sustaining over a million fishermen and significantly contributing to the state's economy. The state has experienced significant marine landings, peaking in 2014 (CMFRI, 2015); however, the marine capture fisheries sector has facing issues such as economic unsustainability and elevated fishing pressure. To resolve these difficulties and guarantee the enduring vitality of marine resources, sustainable management strategies are essential. A notable measure attracting attention is the establishment of a Minimum Legal Size (MLS) for commercially significant fish species.

What is Minimum Legal Size (MLS)?

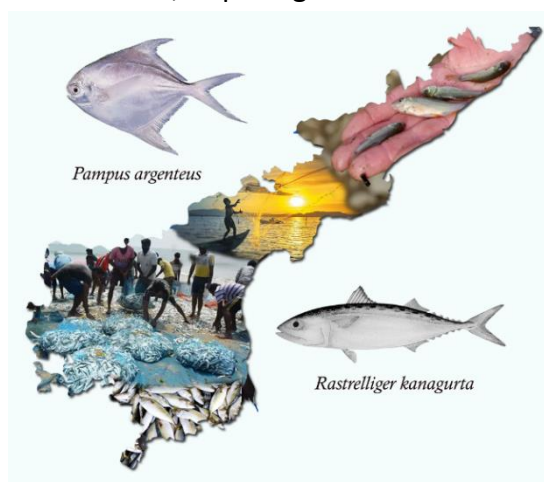
The Minimum Legal Size (MLS) is a fisheries management technique that prohibits the capture of fish below a specified size for a given species (Mohamed *et al.*, 2014). The primary objective of establishing a Minimum Legal Size (MLS) is to guarantee that the majority of fish can reproduce at least once prior to being harvested. This measure aims to avert the premature extraction of fish from the population, thereby enabling them to participate in the reproductive cycle and restore stocks.



Fig.: Juvenile Fishing

The Need for MLS in Andhra Pradesh

Currently, no state in India, including Andhra Pradesh, imposes restrictions on the total number or quota of fish that can be caught (Muktha *et al.*, 2018). Nonetheless, imposing a limitation on the size of fish caught is regarded as an effective regulatory strategy. The sources underline that the maritime fisheries of Andhra Pradesh are vulnerable to overexploitation. There is extensive exploitation of fish stocks, with marine landings frequently exceeding the anticipated potential yield. Furthermore, the increasing usage of gears like ring seines with very fine mesh sizes in inshore seas typically results near catches constituted virtually completely of juveniles and sub-adults. This "irrational removal of juveniles" leads to growth overfishing, when fish are grabbed before they have had a chance to grow to their full potential size, reducing the total productivity of the stock. The study indicates that numerous species in Andhra Pradesh are observed to be developing at smaller sizes in recent years, which could be a result of increased fishing pressure, environmental changes, or a



combination of both. Fixing an MLS can help restrain this trend and prevent the fall of maturity sizes. MLS is viewed as a vital output control measure that, if applied, would enable most fish to reproduce at least once before being caught.

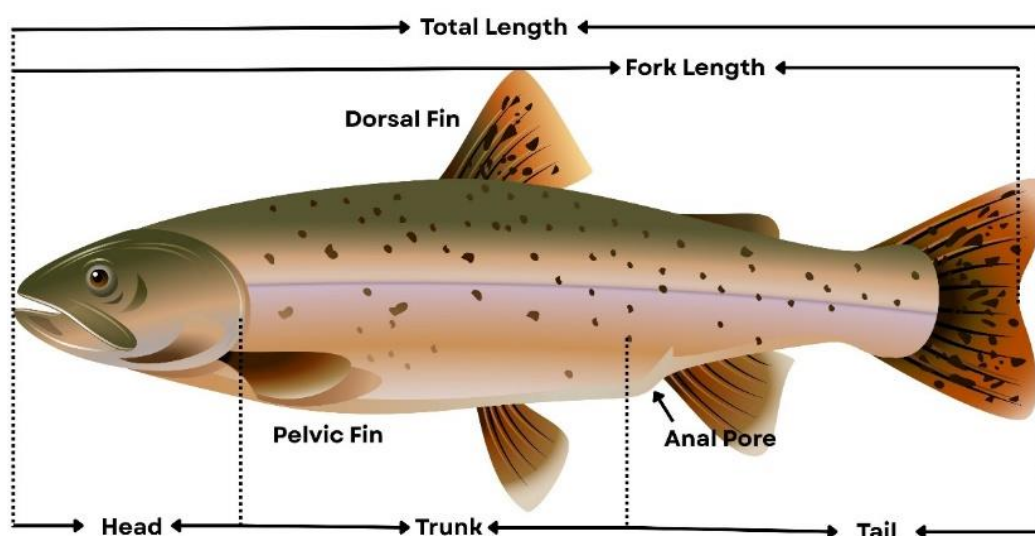
Recommendations for Implementation

The ICAR- Central Marine Fisheries Research Institute (CMFRI) has developed a number of suggestions for the sustainable management of Andhra Pradesh's marine fisheries, including the use of MLS for important commercial marine species, based on in-depth research.

The MLS is estimated based on the Minimum Size at Maturity (MSM) and the Size at First Maturity (SFM). SFM is often a more conservative approach and is preferred for species considered more fragile.

For successful implementation, it is proposed that if more than 50% of a vessel's landings for a given species are found to be at sizes smaller than the acceptable MLS, the vessel owner or operator should be punished.

Recommended Minimum Legal Sizes for Finfish



Annexure I of the document provides a list of recommended Minimum Legal Sizes for 61 marine fish and shellfish species in Andhra Pradesh, based on MLS estimates for Kerala and Tamil Nadu.

Focusing on finfish (Pelagic and Demersal species), the recommended MLS values are presented below:

Table 1. Recommended Minimum Legal Size (MLS) for pelagic and demersal finfish species in Andhra Pradesh

Pelagic finfish		Demersal finfish	
Species	Length	Species	Length
<i>Amblygaster sirm</i>	11 cm TL	<i>Nemipterus japonicus</i>	12 cm TL
<i>Escualosa thoracata</i>	9 cm TL	<i>Nemipterus randalli</i>	10 cm TL
<i>Sardinella albella</i>	10 cm TL	<i>Saurida undosquamis</i>	10 cm TL
<i>Sardinella fimbriata</i>	11 cm TL	<i>Priacanthus hamrur</i>	15 cm TL

Pelagic finfish		Demersal finfish	
Species	Length	Species	Length
<i>Sardinella gibbosa</i>	10 cm TL	<i>Pampus argenteus</i>	13 cm TL
<i>Sardinella longiceps</i>	10 cm TL	<i>Pampus chinensis</i>	30 cm SFM
<i>Stolephorus indicus</i>	10 cm TL	<i>Otolithes ruber</i>	17 cm TL
<i>Caranx ignobilis</i>	55 cm TL	<i>Johnius carutta</i>	16 cm TL
<i>Rastrelliger kanagurta</i>	19 cm TL	<i>Nibea maculata</i>	15 cm TL
<i>Trichiurus lepturus</i>	46 cm TL	<i>Pennahia anea</i>	13 cm TL
<i>Auxis thazard</i>	25 cm FL	<i>Psettodes erumei</i>	20 cm TL
<i>Euthynnus affinis</i>	31 cm FL	<i>Lutjanus johnii</i>	55 cm TL
<i>Katsuwonus pelamis</i>	35 cm FL	<i>Lutjanus argentimaculatus</i>	50 cm TL
<i>Thunnus albacares</i>	50 cm FL	<i>Platycephalus indicus</i>	30 cm TL
<i>Scomberomorus commerson</i>	50 cm FL	<i>Cynoglossus macrostomus</i>	9 cm TL
<i>Scomberomorus guttatus</i>	40 cm SFM	<i>Carcharhinus falciformis</i>	180 cm TL
<i>Coryphaena hippurus</i>	38 cm FL	<i>Gymnura poecilura</i>	50 cm DW
<i>Megalaspis cordyla</i>	19 cm TL	<i>Neotrygon indica</i>	33 cm DW

***TL: Total length, FL: Fork Length, DW - Disc Width, SFM: Size at First maturity**

(Source: Muktha *et al.*, 2018)

Conclusion

The adoption of Minimum Legal Size (MLS) restrictions for commercially important finfish species in Andhra Pradesh is a vital step towards attaining sustainable marine fisheries. By allowing fish to reproduce before being caught, MLS helps prevent growing overfishing, solves the issue of diminishing size at maturity, and contributes to the long-term health and ecological integrity of the state's marine living resources. Alongside other recommended measures like restricting fishing effort, mesh size limitations, and habitat restoration, enforcing MLS will help give the fishermen of Andhra Pradesh a stable future built on sustainably managed resources.

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MICROBES AS MISSILES - THE GROWING THREAT OF BIO WARFARE

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Abstract

While war is often associated with missiles and battlefields, a quieter and potentially more devastating threat looms over our food system – agroterrorism. This article explores the deliberate introduction of microbes and pests as biological weapons to attack crops and livestock. From historical examples of microbial warfare to the 2025 smuggling case involving *Fusarium graminearum*, the piece aims to share how easily accessible pathogens can become tools for destruction. It also highlights the reasons for agricultural lands being vulnerable targets and how farmers and citizens can recognize and respond to such threats. The article underscores the need for collective awareness, surveillance, and biosecurity to protect the future food supply.

Keywords: Agroterrorism, microbes, *Fusarium graminearum*, food security

Introduction

We often picture loud explosions, tanks, and troops when we think of any war. But, what if the real danger is something which we can't see? What if the next mass-destructive weapon isn't a missile but a teeny tiny microbe? Although this is something we ponder, the idea of using microbes in warfare is not recent. This had been 'claimed and confirmed' later to be used by several groups clandestinely over a period of time. Agroterrorism is a form of biowarfare that deliberately introduces toxic and pathogenic agents into agricultural fields, livestock, or water supply to cause diseases, economic destabilization, panic, and mortality. This form of biowarfare does not strike cities and people, but crop fields and farms. It is silent, sneaky, invisible, and comes without sirens or smoke. A few inoculums dispersed at the right time and place would be sufficient to cause devastating losses crippling the nation from the grassroots level.

A Weapon Hidden in Plain Sight

Agroterrorism, as the name indicates, uses biological agents such as plant pathogens, pests, or toxins to attack crops and cattle on purpose. This war form aims to create chaos without firing a single bullet. The most dangerous disease-causing agent occurs naturally and requires no high-tech labs or billions of funding to pull off an attack. A person with fundamental knowledge of plant pathology or microbiology or even a 'farming enthusiast', can access infected materials and can potentially cause large-scale damage to crops with just basic laboratory facilities. On 13th May 2020, India encountered a severe threat as swarms of desert locusts, originating from East Africa and Southeast Asia, made their way into Rajasthan and then to other states, attacking vast stretches of agricultural fields, posing a serious threat to the nation's food security. Although this attack was

reported and opined to be driven by climate change, it obviously raised a vital question. What if such an attack had been intentional?

History offers compelling examples of microbes as weapons:

1. U.S.–Japan Tragedy

The U.S. initiated a large-scale biological weapons program to counter those of Japan and Germany. It had been reported in the declassified documents that the U.S. initially planned to destroy Japan's rice fields but chose to use an atomic bomb (Datta *et al.*, 2020).

2. Iraq-Iran War, 1980s

During the 1980s, the Iraqi government under Saddam Hussein clandestinely experimented with wheat smut fungi and aflatoxin-producing strains of *Aspergillus*, both of which can destroy grain crops and contaminate food. Concerns arose with Iraq's potential use of these pathogens to cripple the Iranian agriculture (M *et al.*, 2024).

3. Al-Qaeda's Interest, 2000s

In the aftermath of the 9/11 attacks, the U.S. military found documents outlining Al-Qaeda's interest in using biological weapons, including wheat rust fungi as a potential weapon to harm the U.S. economy (Gill, 2015; Suffert *et al.*, 2009).

4. India's Cotton Crisis, 2015

In 2015, two-thirds of the cotton crops in Punjab were lost due to Cotton Leaf Curl Viral Disease. Previously, Cotton Leaf Curl Viral Disease outbreaks in Pakistan preceded infections in India. Unusually, the virus sequence associated with the 2015 Cotton Leaf Curl Virus Disease has not been reported from any farmer's field in Pakistan to date. However, interestingly, this same virus has been reported from two cotton research institutes in Pakistan's Punjab Province (Datta *et al.*, 2020).

5. U.S. *Fusarium* Smuggling Case, 2025

In June 2025, U.S. authorities arrested two Chinese researchers for allegedly smuggling *Fusarium graminearum*, a highly toxic fungus into the U.S. without proper authorization. This fungus is responsible for causing Fusarium head blight disease in cereal crops like wheat, barley maize and rice, which can lead to substantial crop losses. The fungus also produces mycotoxins that can affect humans and animals. (TOI World Desk, 2025)

Why Fields and Farms Are Easy Targets?

Unlike military bases and cities, agricultural lands are vast, isolated and largely unprotected, making these fields a vulnerable spot for sneaky malicious activities. Over and above, quarantine systems in the country remain a concern for all. For countries like India, whose economy is dependent on agriculture, the destruction of agriculture can dismantle the country's economy. Below are some of the reasons why crops are tempting targets for agroterrorism:

- **Easily Accessible:** Agricultural lands are large, isolated and lack stringent surveillance as compared to settlement areas. This makes it easy for the attacker to spread the pathogens unnoticed.
- **Monocropping:** Planting a single crop over a large continuous area is not advisable even under normal situations, as it creates a highly favourable environment for the pathogen to thrive. Under deliberate attacks, large-scale monocropping serves as a cherry on top to the attacker's plan.

- **Delayed Detection:** In contrast to humans, sick plants fail to complain, making the detection of the presence of a pathogen possible only after the appearance of obvious symptoms. Crops like rice and wheat, which are staples of most countries, are annual crops, making their management meaningless once it is severely infected.
- **Highly Infectious Agents:** Pathogens that can spread rapidly and cause epidemics are usually favoured in agroterrorism. For example, smut and rust fungi have been found in various instances due to the easy dissemination of these pathogens by wind.
- **Low-Tech Sabotage:** Culturing these pathogens does not require high-end fancy laboratories; basic equipment and knowledge are sufficient.

Could You Spot an Agroterror Attack?

The answer is yes, although difficult. Agroterror attacks can be crippling but it is not like a dramatic event where everything will disappear in seconds. It is a silent invasion, but there will be cues that could point to something suspicious. In case of an agroterror attack, farmers are the first line of defense, but every citizen must have the responsibility to stay alert if they observe any kind of potential danger. Here are some signs of a possible attack:

- Sudden and unexplained death and damage among crops or/and livestock.
- Emergence of a new disease that was not reported/recorded earlier, simultaneously in different regions.
- Highly productive or staple crops are targeted, unlike in natural cases, where infection occurs irrespective of the productivity.
- In case of vector-borne diseases, unpredictable patterns in vector population dynamics.
- Failure of standard treatments and resistant varieties.

What Can Farmers and the Public Do?

- Report unusual crop symptoms to local agricultural officers or the subject matter specialists in Krishi Vigyan Kendras or Agricultural Universities/ Colleges.
- Familiarize with mobile applications such as Kisan Suvidha for expert analysis.
- Avoid sourcing seeds or planting materials from unknown sources.
- Form local crop-monitoring groups to enable early detection.

Global Defense Against the Invisible

Microbes do not need a visa to travel and know no borders. A disease epidemic in a region can spread quickly and turn into a pandemic, threatening global food security. Although not a plant disease epidemic, the COVID-19 pandemic greatly impacted human health across the globe, swiftly, just because of a small virus. Recognizing the dangers, international organizations and governments have initiated collaborative measures to strengthen the agricultural defense:

- Since 2018, FAO, WOA, and INTERPOL have partnered to enhance preparedness against agro-crime, including agroterrorism, by conducting joint simulation exercises and training sessions.
- IPPC developed the International Standard for Phytosanitary Measures to prevent the accidental introduction and spread of pests and facilitate safe trade among member countries.
- India's NDMA guidelines on agroterrorism emphasize early detection, lab preparedness, and farmer education.

Final Thoughts: A Shared Responsibility for a Secure Future

A handful of microbes can ‘unthinkably’ do what missiles can’t, dismantle the nation’s economy without making a sound. However, with increased awareness, smart surveillance and international collaboration, agroterrorism doesn’t have to be a looming threat. Farmers, scientists, policymakers, and citizens all ought to play a vital role in keeping our food system resilient. By investing in research, education, and preparedness, we can surely build a future where our fields/ farms are secure and our food supply remains stronger.

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THE CONCEPT OF COMPOSITION, MAGNITUDES AND IMPACTS OF MARINE LITTER IN MANGROVES

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Abstract

Marine litter is one of the most relevant pollution problems that our oceans are facing today. Marine litter in our oceans is a major threat to a sustainable planet. Marine litter is found in virtually all marine and coastal ecosystems around the world; however, most scientific studies, management activities and management record it on beaches. Marine litter significantly impacts mangrove ecosystems, affecting their ecological balance, biodiversity, and overall health. The magnitude of this impact is determined by the amount and type of litter present, with plastic and other debris acting as a source of pollution, hindering natural processes and potentially harming marine life.

Keywords: Marine litter, Mangroves, Pollution, Sustainable development, Global economy

Introduction

Mangroves cover about 13,200,000 ha on tropical and subtropical coasts with a presence in 11 countries. These places are highly important for their wide range of species, food source, tourism, medicinal plants, and forest products. Marine litter is defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environments. Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; accidentally lost at sea; or deliberately left by people on beaches and shores. Plastics are the largest, most harmful and most persistent fraction of marine litter, accounting for at least 85% of total marine waste. Marine litter and plastics have been acknowledged as threat multipliers as they act together with other stressors such as climate change to cause far greater damage than if they occurred in isolation. Some of the linkages between marine plastic litter and climate change represent a direct negative feedback, such as fossil fuel-based plastics causing direct emissions of greenhouse gases through their life cycle.



**Figure 1. Management of Marine litter
(Nandan Das, 2025)**

Marine plastic litter bears social, economic and environmental consequences as it makes its journey from manufacturers to the ocean.

The global load of marine floating plastic litter in surface waters is far smaller than expected based on the loads of mismanaged plastic entering the marine environment. This finding has, therefore, driven attention to the need for identification of the marine sinks holding the missing plastic. Although recent studies, focusing on larger plastic fractions, have revised upwards the load of floating plastic contained in the open ocean, the “missing plastic” remains a large fraction of the expected load, so identifying the marine sinks holding it remains an urgent matter to assess risks and impacts and plan interventions to manage this modern problem. The key role of mangroves as providers of important ecosystem services, including carbon sequestration coastal protection and habitat for marine life requires efficient management of the threats affecting these ecosystems, including marine plastic pollution.

Marine litter

Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; accidentally lost, including material lost at sea in bad weather (fishing gear, cargo); or deliberately left by people on beaches and shores”. Marine litter originates from many sources and causes a wide spectrum of environmental, economic, safety, health and cultural impacts. For example, marine litter can cause harm to sea life if ingested or even death if a marine mammal becomes entangled in litter. Marine litter has been defined by UN Environment as “any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment”.



Figure 2. Marine litter including plastics (Dominguez, 2024)

In addition to the environmental and health problems posed by marine litter, floating garbage and plastics pose a costly as well as dangerous problem for shipping, as they can be a navigational hazard and become entangled in propellers and rudders. This litter is harmful to marine life: sea creatures can become trapped inside containers or strangled by nets or ropes, and microplastics can also enter the food chain as they are indigestible when swallowed. While in estuaries and mangroves, actions related to evaluation studies and solid waste removal activities are limited. The presence and impacts of ML in mangroves have been carried out in Singapore, Brazil, Spain, Indonesia, Tanzania, Saudi Arabia, the Gulf of Aden and the Red Sea. Taking into account that the entry of ML is increasingly recurrent in mangroves and that information about its presence and implications is scarce. The objective of this work was to review the topic in terms of its magnitude, composition,

and impacts caused by BM on mangroves around the world. Marine litter is defined as all human-made solid items that end up in the coastal or marine environment. The major cause is poor waste management and littering on land, although seaborne activities contribute to the problem. The primary source of marine litter is mismanaged plastic waste, which slowly leaks into the environment. In 2018, it amounted to 3 million tonnes. Approximately 80% of marine litter starts on land, while 20% begins at the sea.

Marine Litter composition:

Marine litter composition primarily consists of plastic, which accounts for a large portion of the total debris, followed by paper, rubber, fabric, wood, metal, glass, and other materials. Studies indicate that plastic debris, including fragments and single-use plastics, is particularly abundant.

1. **Plastic:** The most common type of marine litter, accounting for a significant percentage of the total.
2. **Paper:** Paper and cardboard are also found in marine litter, often originating from various sources, including coastal areas and rivers.
3. **Rubber:** Rubber items, such as tires and other rubber products, can also be found in marine debris.
4. **Fabric and Textiles:** Cloth, clothing, and other textiles contribute to the overall composition of marine litter.
5. **Wood and Metal:** Processed wood, metal, and other materials like ceramics and glass are also present in marine litter.
6. **Other Materials:** This category includes various items like fishing gear, hygiene products, and construction materials.

Sources of Marine Litter:

1. **Land-based sources:** The majority of marine litter originates from land, including waste from rivers, storm drains, and coastal areas.
2. **Marine-based sources:** Lost or discarded items from ships, fishing activities, and accidental dumping also contribute to marine debris.
3. **Recreational activities:** Trash from beaches and tourist areas can be a significant source of litter.

The cost of marine litter damage to the global marine economy:

Nations are increasingly aware that the oceans are being impacted by marine litter in a range of ways. Ocean health is now a primary focus of the UN Sustainable Development Goals (SDGs). In support of this, estimation of the direct and indirect costs of damage to communities that rely on marine activities and ecosystem services, provides compelling evidence to policymakers to reverse the global decline of ocean health. Marine litter, sometimes referred to as marine debris,¹ is a man-made material that has entered the oceans as waste. The literature suggests that 80% of marine litter is from land sources, the 20% balance being from activities at sea. In the past 30 years the increased use of plastic, particularly in single use packaging, has led to a high plastic component in marine litter. This plastic has been found to break down into small pieces of microplastic, remaining in the environment unless being physically removed.

Global production of plastic has increased from 100 million metric tonnes (Mt) per annum (p.a.) in 1990 to 322 Mt p.a. in 2015. It is projected to rise to reach 1124 Mt p.a. by 2050 with a cumulative total production since 1950 to 2015 of 25,000 Mt. The increased production of plastic has not been

complemented by waste management capacity and this deviation is now critical. The rates of growth in recycling and incineration over the last 40 years have led to predictions that by 2050 some 94% of all plastics will either be recycled (50%) or incinerated (44%). Current projections suggest the predicted growth in plastic waste will exceed efforts to mitigate it. The increased economic growth in global economies has been accompanied by an increase in the use of plastic in the production and packaging of goods. There is also a failure arising in waste management systems where plastic waste is among “mismanaged waste” and can thus be prone to entering watercourses, streams and rivers, potentially making its way to the sea. The net effect of the sustained economic growth as seen in Gross Domestic Product (GDP) per capita in many Asian economies, has been a rise in marine litter and a deterioration in their environments and human health due to waste-borne diseases. However the trade in plastic waste from wealthier western nations to Asia also contributed to mismanaged waste in those poorer nations and under represented the waste produced by nations such as the United States.

Impacts of Marine litter:

Marine litter is a global environmental concern. Between 61% and 87% of this litter is plastics. Continental plastic litter enters the ocean largely through storm-water runoff, is dumped on shorelines during recreational activities or directly discharged at sea from ships. The deep-sea floor is probably the final global sink for most marine litter that is not decomposed or fractionated to the nano size. In many coastal countries, mismanagement of solid waste has caused between 1.7% and 4.6% of the total plastic waste generated to end up in the sea. The coastal landscape is frequently impacted by marine litter that impairs recreational uses and causes a loss of touristic value. Beyond the aesthetic impact, marine litter also bears potential economic implications to maritime activities, such as fisheries and the aquaculture sectors.

- a) **Entanglement:** Animals can become entangled in nets, ropes, and other debris, leading to injury, drowning, or starvation.
- b) **Ingestion:** Marine animals, including birds, fish, and sea turtles, may mistake plastic for food, leading to starvation, internal injuries, and poisoning from toxic chemicals absorbed by the plastic.
- c) **Habitat Destruction:** Plastic pollution can damage sensitive habitats like coral reefs and seagrass beds, impacting biodiversity and ecosystem function.
- d) **Food Chain Contamination:** Microplastics, small plastic particles, can enter the food chain, potentially affecting marine organisms and even human consumers.
- e) **Introduction of Invasive Species:** Marine debris can act as a transport mechanism for invasive species, disrupting local ecosystems.

Economic Impacts:

- 1) **Tourism:** Marine litter can negatively impact tourism, as polluted beaches and coastlines are less appealing to visitors.
- 2) **Fishing:** Debris, particularly derelict fishing gear, can damage fishing equipment, reduce catches, and pose hazards to fishing operations.
- 3) **Shipping:** Floating debris can be a navigational hazard, leading to damage to ships and potential safety risks.
- 4) **Cleaning Costs:** The cost of cleaning up marine litter, both on beaches and in the water, can be substantial.

Other Impacts:

- A. **Human Health:** Microplastics can enter the human food chain, raising concerns about potential health risks.
- B. **Air Pollution:** Burning of plastic waste can release toxic fumes into the air, contributing to air pollution and respiratory problems.
- C. **Ecosystem Resilience:** Marine litter can weaken the resilience of marine ecosystems to other stressors like climate change.

Impacts on marine litter on mangroves:

Case Study : The current case study was carried out along the coastline of Tuticorin, a district in Tamil Nadu, located in the Go M region on the southeast coast of India (Southwest Bay of Bengal, SW Bo B), covering a 164 km stretch Mangrove flora in this area is moderately distributed in patches, influenced mainly by coastal geomorphology, limited freshwater inflow from upstream sources, significant silt-clay deposition, and minimal tidal variability. The study was conducted from October 2023 to April 2024 in Litter concentration and composition on the mangrove floor. During the belt transect survey conducted across the mangrove floor sampling sites, a total of 6892 pieces of litter were documented. The study indicates a significant amount of litter across the surveyed areas. The average density of litter varied between 1.3 and 23.2 items per square meter (m^2), with a mean concentration (95 % confidence interval) of 6.3 ± 1.9 items/ m^2 . In the present study, it is showed that Mangroves in the surveyed area exhibited a significantly higher Litter concentration and composition on the mangrove floor and trees. The average density of litter varied between 1.3 and 23.2 items per square meter (m^2), with a mean concentration (95 % confidence interval) of 6.3 ± 1.9 items/ m^2 .

Prevention : By using the Driver-Pressure-State-Impact-Response framework to structure the insights from the literature on the main global marine litter problems DPSIR is a useful adaptive management tool to analyse environmental problems and to map potential responses. Moreover, it can be a tool to initiate solutions focusing on sustainable development, hence the SDGs. Studies have shown that in case waste management does not improve profoundly in the coming years, by 2025 the amount of plastic waste entering the ocean from land is predicted to increase by an order of magnitude. Many countries, therefore, focus on the improvement of waste management infrastructure at critical locations. It was mentioned that waste management must be improved by 85% in the top 35% countries of mismanaged plastic waste to achieve a 75% reduction. However, improving waste management infrastructure would require substantial investments (and time), especially in low and middle income countries. The main focus in these countries is on improving solid waste collection and management. Indonesia, for example, has set ambitious targets at the 2017 World Ocean Summit to reduce plastic waste in 25 coastal cities and reduce marine litter by 70% by 2025.

There are also sample examples showing that market-based instruments and legislation, such as waste management policies, bans on certain products, or a plastic bag tax, can be very effective. Strategies aiming at plastic bags, like taxes and charges, have proven to be successful in both developed and developing countries. Market-based instruments, such as bottle deposit refund schemes and container deposit schemes were shown to be effective too.

Conclusion

The constant entry of ML can alter and transform the natural conditions of marine-coastal ecosystems into solid waste dumps. The prop roots and pneumatophores of mangroves act as ML traps, causing several negative effects such as suffocation in seedlings, release of harmful chemicals,

decreased capacity for renewal, sanitation, clogging, accidental ingestion, and physical damage to associated fauna. Yet, there are also concerns about the effectiveness of certain policies because of a lack of monitoring and enforcement. Furthermore it is often difficult to get legal frameworks in place due to political resistance and a lack of cooperation from market parties, while voluntary approaches that are easier to adopt might fail to offer an effective solution.

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BIOLOGY, DISTRIBUTION, AND CONSERVATION CONCERNS OF THE GANGETIC CATFISH *Ailia coila* (HAMILTON, 1822)

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Abstract

Ailia coila (Hamilton, 1822), commonly known as the Gangetic Ailia, is widely distributed in major river systems such as the Ganga, Brahmaputra, and Padma, often inhabiting floodplains, beels, and large river channels. *A. coila* plays a key role in the riverine food web, feeding on aquatic insects and larvae. Breeding is vulnerable to environmental disturbances such as damming and pollution. Recent research has focused on its reproductive biology, feeding ecology, and genetic diversity, highlighting the urgent need for conservation efforts.

Keywords: *Ailia coila*; reproductive biology; feeding ecology; conservation

Introduction

Freshwater ecosystems of South Asia are home to several unique fish species, among which *Ailia coila* (Hamilton, 1822), commonly referred to as the Gangetic Ailia or Indian freshwater catfish, holds ecological and cultural significance. Belonging to the family Ailiidae, this species is frequently found in rivers, beels, and wetlands, contributing notably to inland fisheries and biodiversity. This is a commercially important fishery of the riverine system facing threats from pollution, damming, intensive fishing etc.

Identification and Colour Pattern

Ailia coila features a compressed, elongated body with a small head, terminal mouth, and large, conspicuous eyes. It lacks a dorsal spine, and its long anal fin runs along the underside of the body. The scaleless skin is smooth and coated with mucus. The fish exhibits a silvery body, bluish dorsum, and white ventral surface, while the fins are typically black. Juveniles may display a yellowish tint on the flanks.

Geographical Distribution

The native range of *Ailia coila* spans across India, Bangladesh, Nepal, Pakistan, and Myanmar. In India, it thrives in rivers like the Ganga, Brahmaputra, Mahanadi, and Godavari. It is also prevalent in the Padma, Jamuna, and Meghna river systems in Bangladesh, and in the Terai rivers of Nepal. This species prefers slow-flowing, oxygen-rich habitats such as large rivers and floodplain wetlands, but its populations have declined due to anthropogenic pressures, including overfishing and hydrological alterations.

Food and Feeding Habits

Ailia coila is primarily insectivorous, consuming aquatic insects, larvae, detritus, and trace amounts of plankton. Key dietary items include chironomid larvae, beetle larvae, and caddisflies. Its ability to feed at surface and mid-water levels supports its ecological role in turbid and eutrophic water bodies.

Reproductive Biology

Breeding occurs during the monsoon months (June to August), triggered by increased water levels and temperature. The species attains sexual maturity at 10–12 cm and is a batch spawner. Eggs are

pelagic, non-adhesive, and develop rapidly in warm, oxygenated waters. Fecundity ranges between 3,000 to 10,000 eggs. Environmental disturbances such as pollution and river regulation disrupt natural spawning cycles.

Major Research and Conservation

Recent studies have explored gonadal development, spawning behaviour, feeding ecology, and genetic variability. Institutions like ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI) and Bangladesh Fisheries Research Institute (BFRI) are leading conservation and aquaculture efforts. Conservation strategies should address habitat restoration, pollution control, and restocking of wild populations.

Conclusion

Ailia coila is an ecologically significant yet vulnerable species of South Asian rivers. Understanding its biology and threats is crucial for sustainable fisheries and biodiversity conservation. Urgent intervention through research, policy, and habitat protection is necessary to prevent further population decline.

TYPES OF PIGMENTS IN FRUITS AND VEGETABLES

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Introduction

Two essential physiological processes that affect the quality and marketability of post-harvest vegetables are biosynthesis and color degradation. Complex pathways are involved in pigment production, which is frequently controlled by environmental variables like temperature, light, and ethylene. Both genetic and environmental variables affect the synthesis of anthocyanins, which are mainly responsible for the red, purple, and blue hues (Zhou *et al.*, 2019). Green vegetables turn yellow as a result of chlorophyllase and other enzymes orchestrating the breakdown of chlorophyll, a main indicator of senescence (Jiang *et al.*, 2018). Microbial activity, mechanical damage, and poor storage conditions can hasten color deterioration after harvest. Produce's visual quality is also impacted by non-enzymatic browning, which is caused by lipid oxidation and the Maillard reaction (Cao *et al.*, 2020). Developing storage systems and treatments to extend shelf life and preserve nutritional and aesthetic aspects requires an understanding of these processes.

Significance of Color in Produce

Fruits and vegetables' quality, maturity, and consumer appeal are all greatly influenced by their color. It acts as a visual cue of metabolic alterations that occur throughout ripening and senescence, which are mostly caused by pigment biosynthesis and breakdown processes. Post-harvest pigment deterioration, especially chlorophyll degradation, is an indication of a decline in nutritional and aesthetic value. Unwanted color changes, including browning in cut fruits and vegetables, are caused by non-enzymatic processes like Maillard reactions or enzymatic browning involving polyphenol oxidase (PPO). These processes shorten the shelf life and decrease consumer attractiveness (Gao *et al.*, 2019). The idea of spoiling brought on by the loss of bright color might effect sales and consumer choice. Because anthocyanins are not only colorants but also antioxidants with health advantages, their production is crucial for the post-harvest quality of fruits that have red, blue, and purple hues (Zhou *et al.*, 2019). A decrease in anthocyanin content frequently signifies a drop in both color and nutritional value, making it a useful predictor of nutritional quality (Wu *et al.*, 2020).

Types of Pigments in Fruits and Vegetables

Different pigments, each with unique biosynthesis processes and degradation mechanisms that affect postharvest quality, give fruits and vegetables their vivid colors. Among the primary pigments are:

- 1. Chlorophylls:** Essential for photosynthesis, chlorophylls are what give plants their green color.
- 2. Carotenoids:** These pigments give plants their yellow, orange, and red hues. Geranylgeranyl pyrophosphate is converted to phytoene during carotenoid biosynthesis, which then proceeds to desaturation and cyclization processes to produce molecules such as lycopene and β -carotene. Color and nutritional value may be impacted by postharvest variables like as temperature and light exposure, which can isomerize and degrade carotenoids (Rodriguez-Concepcion & Stange, 2013).

3. Betalains: These substances, which give some fruits and vegetables their red and yellow hues, include beets. They are sensitive to pH and temperature fluctuations and have a different biosynthesis than anthocyanins, which can cause color deterioration after harvest (Gandia-Herrero & Garcia-Carmona, 2013).

Conclusion

Studying the processes involved in pigment biosynthesis and pigment degradation offers important insights into how different elements, including as temperature, light exposure, and storage conditions, affect how quickly produce loses color after harvest. Future study in this area will surely lead to more efficient ways to preserve the pigment integrity of fruits and vegetables after harvest, which will ultimately benefit producers, consumers, and the food sector overall.

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SOIL MICROBIOME AND ITS ROLE IN ENHANCING SUSTAINABLE CROP YIELDS

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Abstract

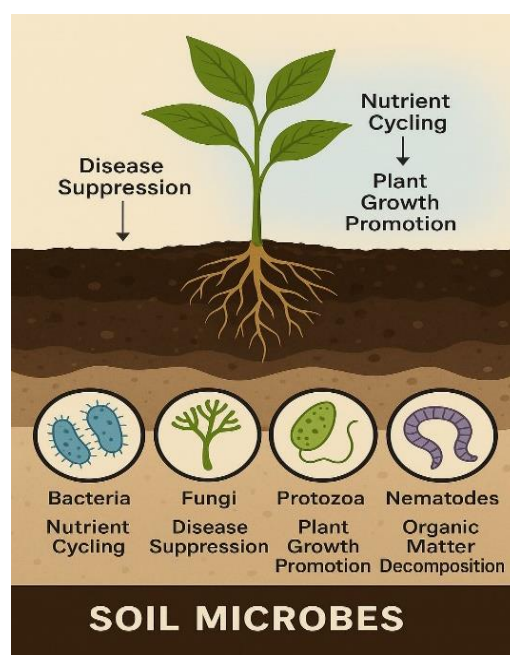
The soil microbiome refers to the diverse community of microorganisms living in the soil, including bacteria, fungi, protozoa, and actinomycetes. These microscopic organisms perform essential functions such as nutrient cycling, disease suppression, and improving soil structure, which directly impact plant health and crop yields. As agriculture faces growing challenges of food insecurity, soil degradation, and climate change, managing and enhancing soil microbiota becomes vital for sustainable farming. This article explores the composition and roles of the soil microbiome, its influence on crop productivity, its applications in agriculture through biofertilizers and biopesticides, and current innovations like microbiome engineering and AI. Utilizing soil microbes offers an eco-friendly approach to boost productivity while preserving environmental integrity.

Keywords: Soil microbiome, crop yield, sustainability, biofertilizer, rhizosphere

Introduction

Modern agriculture must evolve to meet rising food demands without compromising environmental health. Conventional practices have increased productivity but at the cost of soil fertility, biodiversity loss, and chemical dependency. In contrast, the soil microbiome offers a nature-based solution that enhances plant health, improves soil functions, and reduces reliance on agrochemicals.

The soil microbiome consists of beneficial microorganisms primarily bacteria and fungi that colonize the soil and interact with plant roots in the rhizosphere. These microbes play critical roles in nutrient uptake, disease resistance, and stress tolerance in crops. Recent scientific advances have made it possible to understand these microbial communities in more detail and leverage them for sustainable agricultural practices.



Different Microorganisms in Soil and their Roles

1. Understanding the Soil Microbiome

The soil microbiome is composed of:

- **Bacteria:** Key decomposers and nitrogen fixers (e.g., *Rhizobium*, *Azotobacter*)
- **Fungi:** Includes mycorrhizae that form symbiotic relationships with plant roots, enhancing water and nutrient uptake
- **Actinomycetes:** Bridge organisms that decompose complex materials and help in humus formation
- **Protozoa and Nematodes:** Regulate microbial populations and influence nutrient cycling

2. Ecological Functions and Impact on Crops

a) Nutrient Cycling

Microbes convert nutrients into plant-available forms:

- Nitrogen-fixing bacteria convert atmospheric nitrogen into ammonia.
- Phosphate-solubilizing bacteria release phosphorus from bound forms.
- Fungi help mobilize potassium and trace elements.

b) Plant Growth Promotion

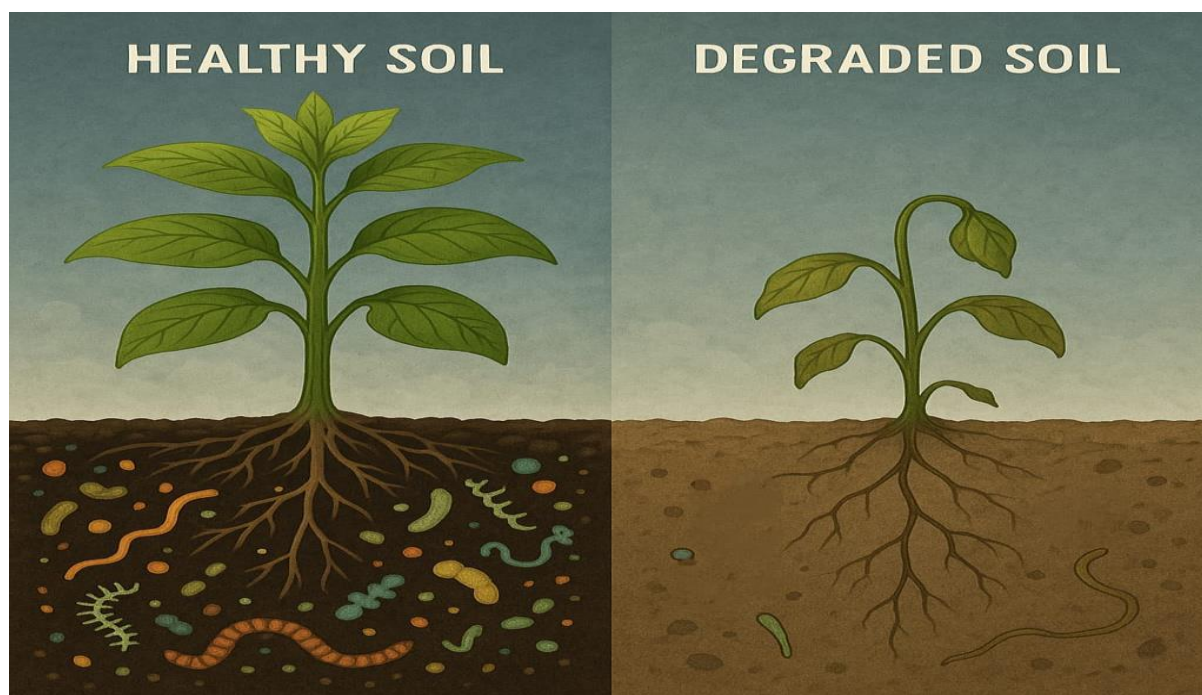
Certain microbes, known as PGPR (Plant Growth-Promoting Rhizobacteria), secrete growth hormones, increase root length, and boost photosynthesis efficiency.

c) Disease Resistance

Biocontrol agents like *Trichoderma* and *Pseudomonas fluorescens* suppress pathogens through competition, antibiosis, or enzyme production.

d) Soil Health and Structure

Fungal hyphae bind soil particles, increasing aeration and water retention. Bacterial biofilms enhance aggregation.



Soil with healthy microbial population vs. Degraded soil.

3. Applications in Sustainable Agriculture

a) Biofertilizers

Microbial inoculants that improve nutrient availability. Common types include:

- *Rhizobium* (nitrogen fixation)
- *Azospirillum*, *Bacillus*, *Pseudomonas* (phosphorus solubilization)
- Mycorrhizal fungi (enhanced root nutrient uptake)

Benefits: Reduced use of chemical fertilizers, improved soil fertility.

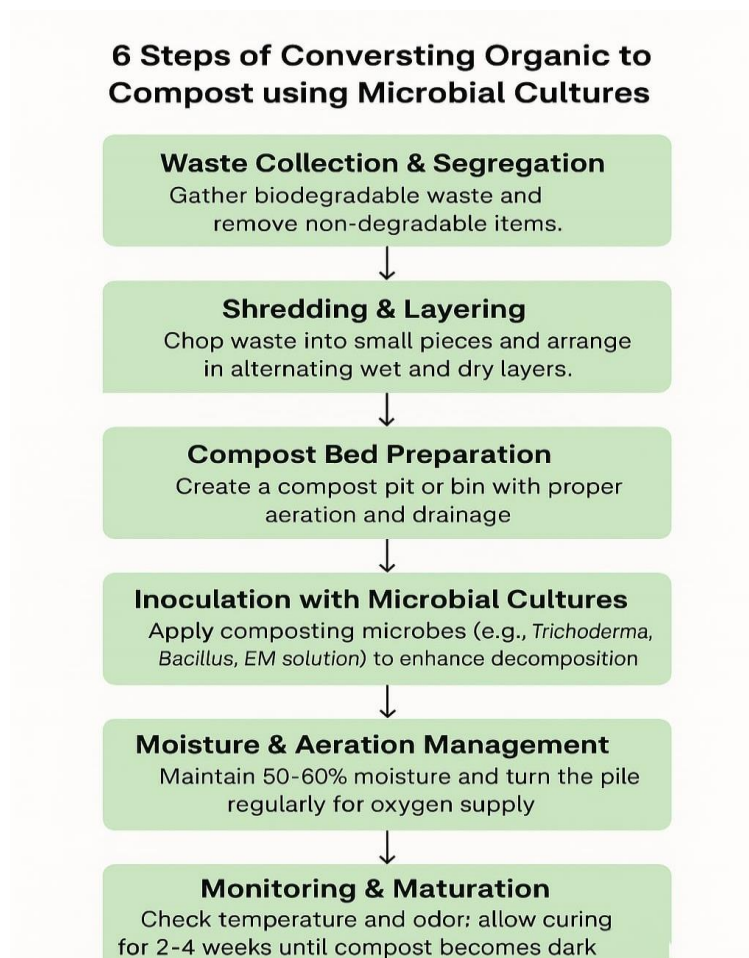
b) Biopesticides

Microbes used to control pests and diseases. Examples:

- *Bacillus thuringiensis* (Bt): Insecticidal properties
- *Trichoderma* spp.: Fungal disease control

c) Enriched Composting

Microbial enrichment of compost and vermicompost speeds up decomposition and enhances nutrient content.



4. Innovations in Soil Microbiome Management

a) Metagenomics

Enables researchers to sequence DNA of soil microbes directly from soil samples, revealing diversity and function without culturing.

b) Microbial Seed Coating

Seeds coated with beneficial microbes ensure early colonization and improve germination and plant health.

c) Microbiome Engineering

Designing synthetic microbial communities tailored to specific crops or environments.

d) AI & Big Data in Microbial Agriculture

Artificial intelligence and predictive analytics are being used to identify beneficial microbial patterns and optimize application timing and dosage.

5. Challenges and Future Prospects

While promising, there are several challenges:

- **Soil variability:** Microbial effectiveness can differ across locations.
- **Limited awareness:** Many farmers lack knowledge or access to microbial products.
- **Regulatory gaps:** Quality control of biofertilizers needs standardization.
- **Environmental sensitivity:** Extreme pH, moisture, or temperature can reduce microbial survival.

Future direction:

- More field trials and localization of microbial solutions
- Policies that incentivize bio-input adoption
- Training programs for farmers and agri-entrepreneurs

Despite these barriers, integrating soil microbiome management into mainstream farming practices offers a sustainable path to resilient and high-yield agriculture.

Conclusion

The soil microbiome represents an essential pillar for sustainable agriculture. Its diverse community of organisms not only supports plant nutrition but also contributes to long-term soil fertility, disease management, and climate resilience. By understanding and harnessing these natural interactions, farmers can reduce their dependency on chemical inputs, increase productivity, and maintain ecological balance.

Modern technologies like metagenomics, microbial seed coatings, and AI-driven data analytics are expanding our capacity to manage the soil microbiome effectively. Moving forward, policies, education, and innovation must align to ensure that farmers especially smallholders can benefit from microbiome-based farming systems.

Investing in the health of our soil microbiome is investing in the future of food, people, and the planet.

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VIRAL DISEASES IN FINFISH

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Introduction

Viral diseases represent a significant challenge to the health and sustainability of finfish populations, both in aquaculture and wild ecosystems. These diseases are caused by a variety of viruses, including Infectious Hematopoietic Necrosis Virus (IHNV), Viral Hemorrhagic Septicemia Virus (VHSV), Spring Viremia of Carp Virus (SVCV), Tilapia Lake virus (TILP), and Infectious Salmon Anemia Virus (ISAV), among others. The impact of viral infections in finfish ranges from subclinical infections to mass mortality events, leading to serious economic losses and disruptions in aquatic food production. With the intensification of aquaculture and global trade in fish and fish products, the risk of viral transmission and outbreaks has increased. Understanding the biology, transmission, clinical signs, and control measures for viral diseases in finfish is essential for effective disease management, biosecurity, and the development of sustainable aquaculture practices.

The major challenges include increase in the number of emerging viral diseases, wild reservoirs, migratory species, anthropogenic activities, limitations in diagnostic tools and expertise, transportation of virus-contaminated ballast water, and international trade. The proposed solutions to these problems include developing biosecurity policies at global and national levels, implementation of biosecurity measures, vaccine development, use of antiviral drugs and probiotics to combat viral infections, selective breeding of disease-resistant fish, use of improved diagnostic tools, disease surveillance, as well as promoting the use of good husbandry and management practices. A multifaceted approach combining several control strategies would provide more effective long-lasting solutions to the reduction in viral infections in marine aquaculture than using a single disease control approach like vaccination alone.

Viral Disease in Finfish

1. Infectious Hematopoietic Necrosis (IHNV)

Causative Agent: Infectious Hematopoietic Necrosis Virus

Infectious Haematopoietic Necrosis (IHNV) is caused by an enveloped single stranded RNA (ssRNA) Rhabdovirus, known as Infectious Haematopoietic Necrosis Virus (IHNV). More detailed information about the disease can be found in the OIE Diagnostic Manual for Aquatic Animal Diseases (OIE 2000a)

Symptoms: IHNV infection in fish can cause a variety of symptoms, including lethargy, darkened skin, exophthalmia (pop-eye), distended abdomen, and pale gills. Additionally, fish may exhibit abnormal swimming patterns like whirling or spiral swimming, and they may have haemorrhages at the base of their fins.

Treatment: IHNV is a highly contagious viral disease in fish, but there is currently no effective treatment for it. Early detection and depopulation of infected fish are the primary methods for managing the spread of IHNV. In India, and globally, prevention through good water quality management, screening broodstock, and disinfection of eggs remains crucial.

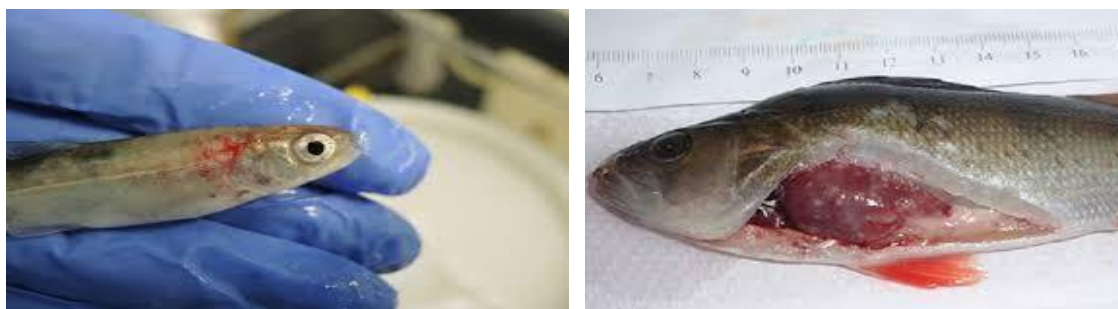


Figure 1: Infectious Haematopoietic Necrosis (IHN)

2. Viral Haemorrhagic Septicemia (VHS)

Causative Agent: Viral Haemorrhagic Septicemia Virus The causative agent of viral haemorrhagic septicemia (VHS) is Viral Haemorrhagic Septicemia Virus (VHSV), a member of the Novirhabdovirus genus within the Rhabdoviridae family. VHSV is a bullet-shaped virus with a negative-sense, single-stranded RNA genome. It's a major threat to cultured rainbow trout and other salmonid species.

Symptoms: Viral Haemorrhagic Septicemia (VHS) in finfish is characterized by a rapid onset of mortality, lethargy, darkening of the skin, exophthalmia (bulging eyes), pale gills, and haemorrhages on the body, eyes, gills, and base of the fins. Affected fish may also exhibit a distended abdomen due to fluid accumulation and abnormal swimming behavior, such as spiraling and flashing.

Treatment: Isolation, destruction and sterile/land-fill disposal of infected fish, as well as susceptible fish exposed downstream, along with disinfection of sites and equipment, has proven effective in controlling losses from this disease. Disinfection requires a minimum of 5 minutes contact with 3% formalin or 100 ppm iodine, 10 minutes with 2% sodium hydroxide and 20 minutes with 540 mg/L chlorine. Fallowing for at least 4 weeks when water temperatures exceed 15°C has also proven effective for re-stocking with VHSV-negative fish. These approaches have led to elimination of VHS from several areas in Europe.



Figure 2: Viral Haemorrhagic Septicemia

3. Spring Viremia of Carp (SVC)

Causative Agent: Spring viraemia of carp Virus (SVCV). Spring viraemia of carp (SVC) is caused by, ssRNA Vesiculovirus (Rhabdoviridae), known as Spring viraemia of carp Virus (SVCV) or Rhabdovirus carpio (RVC).

Symptoms: tissue destruction, hemorrhages, and a variety of clinical symptoms like abdominal distension, exophthalmia, and petechial hemorrhages. Infected fish may also exhibit lethargy, difficulty breathing, and loss of equilibrium.

Treatment: No treatments are currently available although some vaccines have been developed. Most effort is applied to optimising the overwintering condition of the fish by reducing stocking density, reduced handling and strict maintenance of hygiene. New stocks are quarantined for at least two weeks before release into ponds for grow-out.



Figure 3: Spring Viremia of Carp

4. Tilapia Lake virus (TiLV)

Tilapia lake virus (TiLV), is a negative-strand RNA virus that infects both wild and aquacultured populations of tilapia. Tilapia lake virus disease, or syncytial hepatitis of tilapia (SHT), is caused by infection with tilapia lake virus (TiLV). TiLV is an enveloped, negative-sense, single-stranded RNA virus that has been classified as a relative of the Orthomyxoviridae family of viruses.

Symptoms: Affected fish may exhibit signs like sudden mortality, changes in body colour (darkening or lightening), skin erosion, scale protrusion, eye problems, and abdominal distension.

Treatment: To protect tilapia from the TiLV vaccination and biosecurity measures are crucial. Tilapia can develop protective immunity after TiLV exposure, making vaccination a viable option. Several types of vaccines are being developed, including inactivated vaccines, recombinant vaccines, and DNA vaccines. Also, Baicalin is a promising therapeutic drug against TiLV infection.



Figure 4: Tilapia Lake virus

5. Infectious Salmon Anemia (ISA)

Causative Agents: Infectious Salmon Anemia Virus (ISAV)

The disease is caused by ISA virus in the Orthomyxoviridae family; hence, it is related to influenza.

ISA-infected fish may show one or more of the following symptoms:

- Pale gills
- Raised scales

- Pinpoint areas of bleeding
- Bloated abdomen
- Bulging eyes
- Swimming close to the surface

Treatment: To protect fish from Infectious Salmon Anemia (ISA), a combination of biosecurity measures and, in some cases, vaccination is crucial. ISA is a contagious viral disease, and prevention focuses on minimizing the risk of the virus spreading from one fish to another. Some inactivated whole-virus vaccines provide partial protection against ISA, but they can be challenging to administer to large numbers of fish and may not prevent all infections.



Figure 5: Infectious Salmon Anemia

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