

ISSN :3107-4200



VOLUME 3, ISSUE 2
MARCH, 2026-MAY, 2026

An International Newsletter for Agriculture and Allied Sciences

www.sabujeema.in

SABUJEEMA AGRI NEWSLETTER

TRANSFORMING AGRICULTURE



Published by

Society for Agriculture, Allied Sciences and Technology

(Regd under the society regd Act XXI of 1860)

www.saast.co.in





Transition from Chemical Farming to Natural Farming in Paddy and Jowar: A Case Study from Mahabubnagar District, Telangana

Dr. P. Archana¹, Dr. K. Kalyani²

¹Coordinator, TRVK, Mahabubnagar,

²Scientist (CP), TRVK, Mahabubnagar



ABSTRACT

The rising cost of agricultural inputs and declining soil fertility have compelled farmers to explore sustainable alternatives to conventional chemical farming. Natural farming, which relies on on-farm inputs and ecological processes, has emerged as a viable option for improving farm profitability and environmental sustainability. This case study documents the transition of Shri Jnaneshwer, a farmer from Kotakadira village of Mahabubnagar district, Telangana, from chemical-intensive farming to natural farming practices in paddy, jowar, groundnut, and vegetables. The adoption of natural farming techniques such as the application of jeevamrutham, use of natural pest management practices, and elimination of synthetic fertilizers significantly reduced the cost of cultivation and improved soil health. Desi paddy varieties produced yields ranging from 10–15 q/acre and fetched premium market prices between Rs. 100 and Rs. 200 per kg, resulting in benefit–cost ratios ranging from 3.3 to 4.8. Similarly, desi jowar recorded a B:C ratio of 4.4. The results demonstrate that natural farming can enhance farm income, improve soil quality, and ensure sustainable agricultural production.

Introduction

Conventional chemical farming has contributed significantly to agricultural productivity over the past decades; however, excessive use of chemical fertilizers and pesticides has led to soil degradation, increased production costs, and environmental concerns. In recent years, natural farming has gained attention as a sustainable alternative that emphasizes ecological balance, soil health restoration, and reduced dependence on external inputs.



Natural farming practices rely on locally available resources such as farmyard manure, cow-based formulations, crop residues, and biological pest management. These practices not only reduce production costs but also improve soil biological activity and crop resilience.

Shri Jnaneshwer, a 58-year-old farmer from Kotakadira village in Mahabubnagar mandal and district, owns 4.75 acres of land and has more than 15 years of farming experience. Initially, he practiced chemical-intensive agriculture, which resulted in high input costs and declining soil health. Recognizing these challenges, he gradually transitioned to natural farming practices in crops such as desi paddy varieties, jowar, groundnut, and vegetables.

Natural Farming Interventions

The farmer adopted several natural farming practices aimed at improving soil fertility and reducing chemical dependency:

- ✓ Application of Jeevamrutham to enhance soil microbial activity
- ✓ Use of on-farm natural inputs prepared from cow dung, cow urine, jaggery, and pulse flour
- ✓ Adoption of natural pest and disease management practices
- ✓ Complete elimination of chemical fertilizers and pesticides
- ✓ Cultivation of traditional desi paddy varieties with high nutritional and market value
- ✓ Crop diversification including jowar, groundnut, and vegetables

These interventions helped restore soil health while reducing the cost of cultivation.

Crop Performance and Economics

Desi Paddy Varieties under Natural Farming

Variety	Yield (q/acre)	Price (Rs/kg)	Cost of Cultivation (Rs.)	Gross Returns (Rs.)	Net Returns (Rs.)	B:C Ratio
Kujipatalia	15	100	35,000	1,50,000	1,15,000	3.3
Indrani	15	120–150	35,000	2,02,500	1,67,500	4.8



Variety	Yield (q/acre)	Price (Rs/kg)	Cost of Cultivation (Rs.)	Gross Returns (Rs.)	Net Returns (Rs.)	B:C Ratio
Manirathnam	15	120–150	35,000	2,02,500	1,67,500	4.8
Black Rice	10	160–200	35,000	1,80,000	1,45,000	4.1
Kulaker	12	120–150	35,000	1,62,000	1,27,000	3.6
Punager	12	120–150	35,000	1,62,000	1,27,000	3.6

Nutritional and Health Benefits of Selected Varieties

Variety	Special Characteristics
Kujipatalia	Low glycemic index and low fat content
Manirathnam	Reported to help prevent cancer and diabetes
Indrani	Rich in Vitamin D and Vitamin B12; suitable for children

Desi Jowar under Natural Farming

Crop B:C Ratio

Desi Jowar 4.4

Results and Discussion

The transition from chemical farming to natural farming resulted in substantial economic and ecological benefits. The most significant advantage observed was the reduction in input costs, as the farmer relied mainly on locally available natural inputs rather than purchased chemical fertilizers and pesticides. Premium market prices for traditional rice varieties played a crucial role in improving profitability. The benefit–cost ratio for paddy ranged from 3.3 to 4.8, indicating high economic viability. Similarly, desi jowar recorded a B:C ratio of 4.4, further demonstrating the profitability of natural farming.



Apart from economic benefits, improvements were also observed in soil physical and biological properties, including better soil structure, increased microbial activity, and enhanced moisture retention capacity.

The increased consumer demand for chemical-free, nutritionally rich traditional rice varieties also contributed to higher market prices and improved farm income.

Impact

The adoption of natural farming practices led to multiple positive impacts:

- ✓ Significant reduction in cost of cultivation
- ✓ Improved soil fertility and biological activity
- ✓ Higher net farm income due to premium market prices
- ✓ Increased consumer demand for chemical-free produce
- ✓ Reduced dependence on external agricultural inputs
- ✓ Improved sustainability of the farming system

Conclusion

The experience of Shri Jnaneshwer highlights the potential of natural farming as a sustainable and profitable alternative to chemical-intensive agriculture. By adopting natural inputs, cultivating traditional crop varieties, and diversifying cropping systems, the farmer successfully improved soil health, reduced production costs, and increased farm income.

The results suggest that wider adoption of natural farming practices can contribute to economic sustainability, environmental conservation, and improved nutritional security, thereby supporting the long-term resilience of the agricultural sector.

Farmer's Testimonial

“Natural farming reduced my input costs, improved soil health, and increased my net income. It is a sustainable and eco-friendly approach that benefits both farmers and consumers.”



ISSN:3107-4200

SABUJEEMA

Agri Newsletter

An International Newsletter for Agriculture and Allied Sciences



Volume 3 - Issue 02 (Mar-May)-2026



Adoption of Integrated Farming System (IFS) for Sustainable Livelihood Security-A Farmer Success Story

Dr. P. Archana¹, Dr. K. Kalyani²

¹Coordinator, TRVK, Mahabubnagar,

²Scientist (CP), TRVK, Mahabubnagar



INTRODUCTION

Shri Muthyala Veeranjanyulu is a progressive, dedicated, and innovative farmer from Amisthapur village, Boothpur mandal, Mahabubnagar district. He owns 8 acres of agricultural land and has over 28 years of farming experience. Initially, he practiced conventional farming with crops such as paddy, cotton, and groundnut. However, prolonged dependence on monocropping exposed him to production risks, fluctuating market prices, rising input costs, and declining soil health.

Recognizing these challenges and the need for a sustainable and stable income, Shri Veeranjanyulu gradually diversified his farming system by adopting an Integrated Farming System (IFS) approach. His farming model integrates agriculture, horticulture, poultry, and dairy enterprises, making effective use of available farm resources.

His wife, Smt. M. Jyothi, has been a constant source of support and actively participates in farm operations, encouraging the adoption of improved technologies and integrated practices.

Constraints Faced by the Farmer

- Acute labour shortage during peak agricultural operations
- Earlier dependence on a single enterprise
- Limited access to farm machinery
- High incidence of pests and diseases due to monocropping
- Decline in soil fertility and soil health
- Lack of proper storage and marketing facilities



- High cost of agricultural inputs
- Rapid price fluctuations of agricultural produce

Technologies and Interventions Adopted

To overcome these constraints and enhance farm profitability and sustainability, the farmer adopted the following scientific technologies and interventions:

- Cultivation of **High Yielding Varieties (HYVs)** in paddy and redgram
- Adoption of **drip irrigation** for efficient water use
- Use of **power sprayer** for timely and effective plant protection
- Implementation of **Integrated Pest Management (IPM)** practices, including pheromone traps for fruit fly control
- Cultivation of **green fodder crops** for year-round availability of nutritious livestock feed
- Use of **chaff cutter** for efficient fodder processing
- Utilization of own **cultivator** for land preparation, reducing machinery hiring costs
- Construction of a **farm building** for storage of produce, fertilizers, and poultry feed

Motivated by self-reliance and livelihood security, the farmer successfully integrated multiple enterprises, namely: **Agriculture (Paddy, Redgram) + Horticulture (Mango, Guava, Sapota, Marigold) + Poultry + Dairy Farming.**

A key feature of this farming system is **efficient resource recycling**, wherein crop residues and farm by-products are used as livestock feed, and livestock waste is recycled back to the fields to improve soil fertility

Enterprise-wise Details and Economics

Component	Area / Units	Expenditure (Rs.)	Gross Income (Rs.)
Paddy	1 acre	20,000	45,000
Redgram	1 acre	10,000	12,000



Component	Area / Units	Expenditure (Rs.)	Gross Income (Rs.)
Mango	4 acres	1,00,000	4,00,000
Guava	1 acre	30,000	40,000
Marigold	10 guntas	10,000	15,000
Poultry	20 birds	—	—
Dairy	2 cows + 2 calves	—	—
Total		1,70,000	5,12,000

Outcome

- Integration of crops, horticulture, and livestock ensured **year-round income**, reducing dependence on a single enterprise
- Recycling of crop residues and livestock waste **minimized input costs** and promoted on-farm self-sufficiency
- Diversification spread **financial and climatic risks**, preventing total crop failure
- Reduced dependence on external inputs lowered the **cost of cultivation**
- Significant improvement observed in **soil fertility and soil health**
- Overall productivity and farm income increased substantially compared to earlier practices

Impact

- **Gross Returns:** Rs. 5,12,000/- per year
- **Net Returns:** Rs. 3,42,000/- per year

The Integrated Farming System has enhanced the **economic viability, environmental sustainability, and resilience** of the farming system. The farmer achieved improved livelihood security, stable income, and long-term sustainability. This model serves as a **replicable and scalable example** for small and medium farmers in similar agro-climatic regions.



Testimonial of the Farmer

“Earlier, I depended on a single enterprise, so my income was uncertain. After adopting the Integrated Farming System, my farm income doubled and I started earning throughout the year. Recycling methods reduced costs and improved soil fertility. Overall, IFS has made farming more profitable, secure, and sustainable.”





Blossoming Profits Through Agriculture–Floriculture Integration: A success story from Mahabubnagar District, Telangana

Dr. P. Archana¹, Dr. K. Kalyani²

¹Coordinator, TRVK, Mahabubnagar,

²Scientist (CP), TRVK, Mahabubnagar



ABSTRACT

Crop diversification through the integration of floriculture with traditional agriculture can enhance farm profitability and livelihood security for small and medium farmers.

This case study documents the experience of Shri Rajeswer Reddy, a progressive farmer from Divitipally village of Boothpur mandal in Mahabubnagar district, Telangana, who successfully integrated floriculture crops such as rose (cent Rose) and marigold with paddy cultivation. The study highlights the economic performance of these crops and demonstrates the potential of agriculture–floriculture integration for achieving higher income, efficient resource utilization, and year-round cash flow. The results indicate that floriculture crops contributed significantly to farm income, with marigold recording a benefit–cost ratio of 3.4 and rose cultivation providing continuous daily returns.

Introduction

Indian agriculture is increasingly facing challenges such as fluctuating market prices, rising input costs, and climate variability. Under such circumstances, crop diversification has emerged as an effective strategy to improve farm income and reduce economic risks. Floriculture, particularly the cultivation of high-value flowers such as rose and marigold, offers considerable potential for enhancing profitability due to strong market demand and relatively higher price realization.

Shri Rajeswer Reddy, a 50-year-old farmer from Divitipally village of Boothpur mandal in Mahabubnagar district, owns four acres of agricultural land and has about ten years of farming experience. Motivated to enhance farm income and ensure regular cash flow, he adopted an



integrated model combining food crop production with commercial floriculture. Under this system, paddy was cultivated for household food security while rose (cent gulabi) and marigold were introduced as high-value commercial crops. This diversified farming strategy resulted in improved economic returns and better utilization of farm resources.

Technologies and Interventions Adopted

The farmer adopted several improved practices to successfully integrate agriculture with floriculture:

- ✓ Introduction of commercial floriculture alongside traditional food crops
- ✓ Cultivation of perennial rose (cent Rose) for continuous harvest and income
- ✓ Adoption of short-duration marigold varieties for quick returns
- ✓ Strategic crop planning to ensure year-round income generation
- ✓ Adoption of natural farming practices in paddy to reduce input costs

Crop-wise Performance and Economics

Rose (Cent Gulabi)

Rose was cultivated in an area of 0.5 acre with approximately 2,000 plants planted at a cost of Rs. 25 per plant. The crop has a productive life of about five years. The cost of cultivation during the first year was Rs. 1,00,000, while maintenance costs during the second to fifth years were about Rs. 25,000 per year, resulting in a total expenditure of approximately Rs. 2,50,000 over five years. The crop produced an average yield of 20–25 kg of flowers per day throughout the year. With an average market price of Rs. 100 per kg, the annual gross returns were estimated at Rs. 8,21,250, resulting in net returns of Rs. 5,21,250 and a benefit–cost ratio of 1.73.

Marigold

Marigold was cultivated in an area of 0.75 acre with about 6,000 plants (3,000 red and 3,000 yellow). The crop duration was approximately five months. The total cost of cultivation was Rs. 68,000. The average yield recorded was 37.5 quintals per acre, and the average market price was Rs. 80 per kg. The crop generated gross returns of Rs. 3,00,000 and net returns of Rs. 2,32,000, with a benefit–cost ratio of 3.4, indicating high profitability.



Rice

Paddy was cultivated using the varieties RNR-15048 and WGL-1380.

Variety	Yield (q/acre)	Cost of Cultivation (Rs./acre)	Gross Returns (Rs.)	Net Returns (Rs.)	B:C Ratio
RNR-15048 / WGL-1380	27	25,000	54,000	29,000	1.16

Although the returns from paddy were comparatively lower than those from floriculture crops, rice cultivation ensured household food security while maintaining farm sustainability.

Outcome

The integration of agriculture with floriculture resulted in several positive outcomes:

- ✓ Diversified and year-round income generation
- ✓ Continuous daily income from rose cultivation
- ✓ Short-term high returns from marigold cultivation
- ✓ Reduced cost of cultivation in paddy through natural farming practices
- ✓ Improved overall farm profitability compared to mono-cropping systems

Impact

The adoption of floriculture crops significantly enhanced the economic resilience of the farmer. High-value flower crops contributed substantially to net income, while paddy ensured household food security. The diversified farming system minimized production risks and improved livelihood stability. This model demonstrates the potential of integrating floriculture with traditional agriculture to enhance farm income and resource efficiency, particularly for small and medium farmers in similar agro-climatic regions.

Conclusion

The experience of Shri Rajeswer Reddy illustrates that the integration of floriculture with conventional agriculture can substantially improve farm profitability and sustainability. Adoption of high-value flower crops such as rose and marigold alongside staple crops provides continuous income, better land utilization, and enhanced livelihood security. This approach can



ISSN:3107-4200

SABUJEEMA

Agri Newsletter



An International Newsletter for Agriculture and Allied Sciences

serve as a viable model for farmers seeking income diversification and improved economic returns.



Volume 3 - Issue 02 (Mar-May)-2026



ECONOMIC SIGNIFICANCE, CHALLENGES AND FUTURE SCOPE OF EXTRA LONG STAPLE COTTON IN INDIA

M Hari Varshini, A P SriVidhya, J Paul Mansingh

Department of Agricultural Extension & Economics,
VIT School of Agricultural Innovations and Advanced Learning (VAIAL),
Vellore Institute of Technology, Tamil Nadu, India.

INTRODUCTION

Cotton is the pillar of India's agriculture and the textile economy; it is producing the vast diversities of staple lengths. Among the different stable lengths, the Extra Long Staple (ELS) cottons are primarily *Gossypium barbadense*, which is known for its superior fineness, strength and durability. Some of the varieties like Suvin, DCH-32 and MCU-5 are having that capability of spinning a super fine yarns (up to 240s count) which is used for luxury apparels and speciality textiles. The ELS Cotton are mainly defined by its fibre length of more than 30 mm which represents the high value in the global textile market. Despite this, India is the leading textile exporter and has world class research capabilities but it highly relies on the imports to meet the domestic demand.

ELS Cotton varieties

In India ELS Cotton varieties, Suvin is the high-quality type which has the fibre length of about 36 mm and it is very good finest variety that can be spun up to 240s count. And also, some other important varieties developed by the ICAR-CICR for the cultivation in ELS growing region are CICR B Cotton 37, CICR B Cotton 45. Some of the hybrid which is suited for growing in varied agro - climatic environment are Varalaxmi (32mm), DCH-32(33mm), TCHB-213, RHB-388.

Indian status of ELS Cotton

About 2 lakh hectares of cultivation is under ELS Cotton in India, mainly the places like Atpadi in Maharashtra and Coimbatore, Erode, and Dindigul in Tamil Nadu and some of the regions



of the Karnataka, Madhya Pradesh and Andhra Pradesh are the major growers. The demand of the cotton is about more than 10 lakh bales, but the country produces only 3.5 to 5 lakh bales per year. Because of the huge gap between the production and the demand India depends upon the imports to satisfy the needs.

Value addition and export competitiveness

The Indian textile industry is the second largest in the world, yet China is sharing the global market of more than 35% where India is approximately about 5% which lacks behind the China. ELS cotton provides the pathway to fill the gaps by producing the high-quality yarn and fabrics domestically, which shifts the position of India from exporting the raw materials to exporting the high-quality finished goods. ELS Cotton has the premium pricing, and by expanding the cultivation can finance high value garment industries and improve the quality of medium staple blends. By reducing the import dependency and save the foreign exchanges and shields the domestic industry from global price fluctuation.

The “Yarn Forward” Trade Controversy

India proposed the trade agreement with the United States which complicates the economic prospects of farmers. The “Yarn Forward” rule is discussed recently in the trade talks; it says that US cotton can be imported duty free for re-export has a finished garment. So, the farmers group like Samyukta Kisan Morcha fears that it will affect the domestic price of the cotton varieties like Suvin, DCH 32 by providing the subsidised American cotton in the market. While the textile industries advocates that by removing the 11% import duty to stay competitive against the Bangladesh and Vietnam.

Minimum Support Price

For the agricultural year 2025-26, the government set the MSP for cotton fibres measuring 32.5mm and above between Rs 8,310 per quintal for varieties like MCU-5 and Surabhi, Rs 8510 for DCH-32 and Rs 9310 for premium varieties like Suvin. Even though farmer groups like SKM argue that the rates may still fall. According to the M.S.Swaminathan formula, they calculate that Rs 10,075 is required per quintal to cover the cultivation expenses. Farmers are finding harder to get fair price because India is buying twice amount of cotton from USA, spending nearly \$377.90 million in 2025. Farmers are worried that allowing the foreign imports at zero tariff will lead to crash in the global market and destroy the income of local growers who are hardly trying to make profits.



Agronomic constraints

The primary constraint is the low productivity of Indian cotton. India's medium stable varieties yield of about 10 to 12 quintal per acre when it is compared to the s yield it is an average of 7 to 8 quintals per acre. On a global scale India's average cotton yield is approximately about 500 kg per hectare which is far below than the world average is 775 kg per hectare. The ELS varieties also highly sensitive to the pests like pink ball worms and white flies And also requires a long growing season which is responsible for the low productivity in India

Systemic Infrastructure Deficits

Has ELS cotton requires assured irrigation but over 65 % of the India's cotton area is rainfed . The major cotton producing states like Maharashtra and Telangana has less than 25 % of the irrigated cotton area. Indian cotton suffers from high contamination levels, leading to a price discount of 6–7 cents per pound globally. Manual harvesting and poor packing (using non-cotton cloth) introduce impurities that cost the spinning industry ₹7–11 per kg to remove

Policy and Market Barriers

Unlike the major cotton exporting countries like US India lacks systemic bale identification and grading system. And the higher good quality cotton is mixed with the inferior grades which reduces the price of the Indian cotton .And also by the restrictions on the adaptation of the advanced technologies like a hybrid tolerance seed which has the ability reduces the labour cost and Improve the yield but due to the restriction it impacts the farmers economy.

Future Prospects and Opportunities

i The cotton mission 2025-30

Cotton mission 2025-30 has been announced for addressing stagnation issues. Through science and technology support increasing the productivity for ELS varieties is the main objective of this mission. To reduce import reliance, it aims to enhance market linkages and also encourages advanced cultivation technologies.

ii Technological Interventions

Switching to Drip irrigation could boost yield 1,800 to 3,500 kilogram lint per hectare. The future license developing compact plant varieties suitable for mechanical harvesting with the raising labour cost for hand picking.

**iii Branding and traceability**

India must brand its ELS varieties effectively to compete with Egyptian Giza or American pima . By implementing a unique bale identification system that traceability would be ensured and allowing the Indian cotton to command the premium that deserves in the international markets.

CONCLUSION

India stands at an important stage of Extra Long Staple (ELS) cotton. It has a greater potential to become a leading producer in the global market, but currently it yields very low quantity and depends on importing of ELS cotton. Even though India has superior varieties like Suvin and a large textile industry that demands over 10 lakh bales annually, the farmers produce only about 3.5 to 5 lakh bales. This is due to farming risk, water shortage and issues with poor pricing, therefore making industries to depend on imports that are costlier. This creates a conflict among the Industry people and farmers as the industries demand Duty-free US Cotton to reduce costs but farmers oppose it, fearing on price crash and debt crisis. To resolve this fight, the government has introduced " Cotton Mission 2025-30", with an aim of reuniting the both farmers and industries by introducing advanced seeds modern irrigation practices and promoting Indian ELS cotton as a premium product. This ensures that it serves both the industrial and farming community

REFERENCE

1. Dhuria, I. J. "Issues Confronting the Indian Textile Industry." Cotton Statistics & News, edited by Amar Singh, no. 8, Cotton Association of India, 22 May 2018, pp. 1-5.
2. Chockalingam, M. M. "A Profile of Indian Cotton: At a Glance.". (Note: The exact publication container and date are not explicitly stated in the document, though the text references the 2015-2016 cotton season.)
3. Manickam, S. "Extra Long Staple Varieties and Hybrids in Cotton." Model Training Course on "Cultivation of Long Staple Cotton (ELS)", ICAR-Central Institute for Cotton Research, Dec. 2007, pp. 54-58.
4. Dhamayanthi, K. P. M., and A. Manivannan. "Status on Extra Long Staple Cotton in India." Lecture Notes of Exposure Visit cum Capacity Building Program on Cotton Production Technologies, ICAR-Central Institute for Cotton Research, Nov. 2019, pp. 12-17.



5. USDA Foreign Agricultural Service. (2024). Cotton and products annual: New Delhi, India (Report No. IN2024-0017).
https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Cotton%20and%20Products%20Annual_New%20Delhi_India_IN2024-0017.pdf
6. USTHadian. (n.d.). National ELS cotton drive: Raising fibre standards and farmers' incomes. <https://www.usthadian.com/national-els-cotton-drive-raising-fibre-standards-and-farmers-incomes/>
7. Cotton Farmers Protest Piyush Goyal's Remarks on US Imports, Warn of Price Crash." The Hindu. <https://www.thehindu.com/business/agri-business/cotton-farmers-protest-piyush-goyals-remarks-on-us-imports-warn-of-price-crash/article70635962.ece/>
8. Textile Commissioner's Office, Government of India. MSP Order 2025–26. <https://www.txcindia.gov.in/html/MSP%20Order%202025-26%20-%20English.>





ARE SMALL FARMS MORE PRODUCTIVE THAN LARGE FARMS?

Poshika R (UG Student), A P SriVidhya (Research Scholar), J Paul Mansingh* (Professor)

**Department of Agricultural Extension & Economics,
VIT School of Agricultural Innovations and Advanced Learning (VAIAL),
Vellore Institute of Technology, Tamil Nadu, India.**



INTRODUCTION

We always think that large farms are more Productive? Do you think YES? We examine the same whether small farms are more productive than large farms in India. This article reviews recent government initiatives inclusive of digital infrastructure, AI-based guidance, targeted district policies and programs, natural farming campaigns and green mechanization developments are aimed at supporting small farmers and increasing agricultural turnovers in a sustainable way. This article assembles insights from recent studies, news reports, and government data to provide an overview of farm productivity trends in India. The connection between the size of the farm and production per unit area in developing countries is debated for a long time. A study was performed by Indian Institute of Technology, Bangalore and University of Hyderabad. The researchers of this research relied on rural data from International Crops Research Institute for Semi-Arid Tropics (ICRISAT) between 1975 to 2014.

Insights into the research on productivity

The researchers found that small farms gave more production, especially between 1975 and 1984. This shows an inverse relationship, which means that as farm size increases, production per unit area decreases. However, the study also points out that this inverse relationship was not very strong in the semi-arid regions of India.

Earlier, it was explained that small farmers achieved higher productivity because they use more family labor, take more personal care of their crops, and use more fertilizers and other inputs per unit of land. However, the inverse relationship has diminished over time. Smallholders initially had higher yields, but by 2009–14 their advantage had weakened significantly due to



high input costs and monocropping. The study also states that both labor and other inputs like seeds, fertilizers, and machines are closely connected to higher productivity. Therefore, productivity does not mainly depend on farm size, but on how well the land is used and managed.

Structural Realities Facing Small Farms

Around 86% of farmers in India own small and marginal farms. Since they have small land, they don't get access to machines, loans and proper farming advice. To the fact that they don't get resources properly, productivity will be low. Farmers who own small and marginal level lands need to get more support and access to technology. They also need access to good inputs for their farms. If they get proper help and support small farmers also can show more productivity.

Policy and Innovation Pathways

The recent Union Budget has introduced several reforms to improve agricultural productivity. One major focus is on technology and digital infrastructure. The government plans to promote AI-based tools for crop planning, weather alerts, and pest management through the Bharat VISTAAR platform. A Digital Public Infrastructure (DPI) will also be developed over the next three years to conduct digital crop surveys and register nearly 6 crore farmers. The budget also focuses on improving productivity in low-performing areas. Under the Pradhan Mantri Dhan-Dhanya Krishi Yojana (PMDDKY), 100 low-productivity districts will be targeted, covering about 1.7 crore farmers. The scheme's target is to improve irrigation facilities and provide better access to credit.

In addition, the government has announced a National Mission on Natural Farming (NMNF) with an allocation of Rs. 2481 crore. A five-year mission has also been introduced to improve cotton productivity and encourage sustainable farming practices. These initiatives are aim to increase overall turnover while ensuring long-term renewable in agriculture.

In November 2025, Agriculture Secretary Devesh Chaturvedi 9th EIMA Agrimach India event stated that the government will give priority to green fuel-based farm machinery and improve access to mechanization for small and marginal farmers. He explained that mechanization is important for increasing farmers' income by reducing farming costs and improving productivity. These steps are part of India's long-term goal of becoming a global food basket



by 2047. By promoting affordable and eco-friendly machinery, the government aims to support small farmers and help them increase their output.

Conclusion

There is no proper answer for the question are small farms more productive than large farms. In earlier times researches have said small farms produced more per unit area, but the trend is diminishing recently. It is because productivity doesn't only depend on farm size, they also depend on many factors like, labor, inputs, machineries, credits etc., To support small farmers, the government is also focusing on new technologies such as AI based advisory systems, digital systems and many development programs. Small farmers can use these initiatives to attain more productivity.

References

1. <https://researchmatters.in/news/do-small-farms-outperform-big-ones-study-reveals-changes-over-40-years-india>
2. <https://eng.ruralvoice.in/national/are-small-farms-more-productive-a-new-study-challenges-the-long-held-belief.html>
3. <https://m.economictimes.com/news/economy/agriculture/budget-2026-nirmala-sitharaman-india-agriculture-farm-sector-revival-agri-reforms-farmers-welfare/articleshow/126498739.cms>
4. <https://m.economictimes.com/small-biz/sme-sector/govt-to-push-green-fuel-farm-equipment-boost-access-for-small-farmers-agri-secy/articleshow/125629610.cms>
5. <https://www.thehindu.com/sci-tech/agriculture/small-farms-are-more-productive-than-large-farms-finds-study/article70046353.ece>
6. <https://www.iitb.ac.in/research-highlight/do-small-farms-outperform-big-ones-study-reveals-changes-over-40-years-india>



Self-Employment and Agricultural Schemes for Ex-Servicemen Farmers in India

Subashree A, A P SriVidhya, J Paul Mansingh*

VIT School of Agricultural Innovations and Advanced Learning (VAIAL),
Vellore Institute of Technology, Tamil Nadu, India



INTRODUCTION

India has always placed great importance on supporting its ex-servicemen after they retire from military service. Adjusting from military life to civilian life can be challenging. For, many ex-servicemen and war widows, agriculture and rural based enterprises offer reliable and employment opportunities. Assist in this transition, the Directorate General Resettlement (DGR) under the Ministry of Defence provides guidance and support to ex-servicemen who wish to start their own self-employment. While individuals are free to choose the type of project they want to undertake, dgr helps them understand the available financial schemes, subsidies, and institutional support systems. This guidance makes it easier for ex-servicemen to begin self-employment activities, especially in agriculture and rural industries.

Institutional support for ex-servicemen farmers

In India, certain national institutions play an important role in promoting rural development and self-employment opportunities. The most significant organisation supporting ex-servicemen farmers is “National bank for agriculture and rural development (NABARD)”. It provides financial assistance, refinance facilities, interest subsidies, and training programmes. Their schemes mainly focus on agriculture, rural industries, which are suitable for people settling in rural areas after retirement.

The schemes that are available for the ex-servicemen

- A. SEMFEX-ii
- B. SEMFEX-iii
- C. Allotment of mother dairy milk booths and safal shops

**A. SEMFEX-ii (Arms to Farms)**

One of these major schemes introduced for ex-servicemen is the self-employment scheme for ex-servicemen, commonly known as SEMFEX-ii. This scheme has been in existence since 15 January 1988. It was designed as a credit-linked programme to help ex-servicemen establish sustainable livelihoods after leaving the armed forces. The scheme also supports disabled service personnel, war widows, and widows of ex-servicemen. SEMFEX-ii is often referred to as the “arms to farms” initiative because it motivates retired defence personnel to move from military service into farming and other rural business activities. The programme is implemented with financial assistance from NABARD. The phrase “from arms to farms” symbolises the journey of soldiers who dedicate their early years to national defence and later contribute to the country’s agricultural development

Eligible activities

The scheme supports a wide range of agricultural and rural livelihood activities. Some of the commonly supported activities include

- Minor irrigation projects
- Poultry farming
- Farm mechanisation
- Sheep and goat rearing
- Mushroom cultivation
- Dairy farming
- Plantation and horticulture crop

In addition to these activities, NABARD also provides support for:

- Biogas unit installation
- Handloom and handicraft production
- Agro-processing industries
- Service sector activities in rural areas



Loan agencies

Loans under the SEMFEX-ii scheme can be obtained from several financial institutions, including

- Commercial Banks
- Co-Operative Banks
- Regional Rural Banks (Rrbs)
- Scheduled Primary Urban Co-Operative Banks

Benefits of the scheme



Figure 1. Benefits of the SEMFEX Scheme

Disadvantages of the scheme

- Although the scheme exists, the final approval of loans depends on banks, which may require detailed project reports.
- The application process involves documentation and verification through institutions such as the zila sainik board, which may take time.
- If the agricultural project fails due to market or climatic conditions, farmers must repay the loan.

B. SEMFEX-iii

Another important scheme is SEMFEX-iii, also known as “Sena Se Gramodyog.” This programme is implemented with the support of the Khadi and Village Industries Commission (KVIC). The primary aim of this scheme is to support ex-servicemen and war widows by helping them establish small rural industries and village based enterprises. Under SEMFEX-



iii, ex -servicemen are given priority when applying for loans to start rural enterprises. One of the major advantages of this scheme is the low margin requirement. The borrower is required to contribute only 5% of the project cost as margin money. The remaining 95% of the project cost is financed through institutions such as

- KVIC
- KVIB
- Sainik Sahakari Bank Ltd
- Scheduled Commercial Banks
- Regional Rural Banks

Applicants also receive training and technical guidance. KVIC and KVIB training centres organised the free training programmes to participants understand business management and production techniques.

Conclusion

Self-employment schemes created for ex-servicemen are extremely helpful in supporting their transition from military life to civilian occupations. Programmes such as the self-employment scheme for ex-servicemen (SEMFEX-ii) provide financial support, loans, and training that allow retired soldiers to start their own agricultural or rural enterprises. Many ex-servicemen successfully run dairy farms, poultry units, and small agro-based businesses with the help of these schemes. Although there can sometimes be challenges such as paperwork or delays in loan approval. Overall, these initiatives not only improve the livelihood of ex-servicemen but also contribute to the development of rural communities and the agricultural sector.

References

- <https://agritech.tnau.ac.in/horticulture/semfex.pdf>
- <https://sandeepans.com/wp-content/uploads/2017/04/brochure-for-veterans-and-nok-army-hq.pdf>
- <https://www.tn.gov.in/rti/proactive/public/handbook-exservice.pdf>
- <https://dnv.indiannavy.gov.in/sites/default/files/repository-document/DGR%20Directorate%20of%20Entrepreneurs%20and%20Loans.pdf>



IRRIGATION WATER DISTRIBUTION PRACTICES IN INDIA

Ajmal Siddique S^{1*}, Anwesha Barman¹

¹Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore – 641 003,
Tamil Nadu, India.



ABSTRACT

Irrigation is essential for agricultural development, supporting food security, economic growth, and livelihoods. It involves the artificial supply of water to crops, especially in regions with uncertain rainfall. In India, irrigation has evolved from traditional systems like wells, tanks and canals to modern methods such as sprinkler and drip irrigation. These systems enhance crop productivity, cropping intensity, employment, and drought resilience. However, irrigation also poses challenges like soil salinity, environmental degradation and water mismanagement. Sustainable solutions, including efficient water use, improved management practices and integration of traditional and modern techniques are necessary to ensure long-term agricultural productivity and environmental sustainability.

Keywords: Water distribution, Traditional irrigation, Agriculture, Smart irrigation

Introduction

Irrigation is the lifeline of agriculture, involving the artificial supply of water to support crop growth when rainfall is inadequate. It has shaped civilizations, boosted productivity and supported economic and social development. Farmers rely on irrigation to manage droughts, maintain soil moisture, prevent frost damage and remove excess salts, while also creating a favorable environment for crops. With increasing climate change and erratic rainfall, dependable irrigation systems are more important than ever. In India, where agriculture sustains livelihoods, diverse methods such as wells, tanks, canals and river valley projects have evolved, blending traditional knowledge with modern technology to support resilient and efficient farming system.



History of Irrigation Development

Historically, the development of irrigation has been closely linked with the growth of civilizations, as it provided a stable agricultural base for societies. Archaeological evidence reveals that irrigation practices existed in ancient Mesopotamia and Egypt as early as the 6th millennium BCE. In these regions, crops such as barley were cultivated in areas where natural rainfall was insufficient, necessitating artificial water supply systems.

The Indus Valley Civilization, located in present-day northwestern India and Pakistan, also demonstrated advanced irrigation practices around 2600 BCE. Large-scale agriculture was supported by an extensive network of canals. Evidence of sophisticated water management systems, including reservoirs such as those built at Girnar around 3000 BCE, highlights the advanced engineering skills of early civilizations.

Irrigation Development in India

Ministry of water resources (Govt. of India), briefly explains the history of irrigation development in India which can be traced back to prehistoric times. Vedas, ancient Indian writers and ancient Indian scriptures have made references to wells, canals, tanks and dams. These irrigation technologies were in the form of small and minor works, which could be operated by small households to irrigate small patches of land. In the south, perennial irrigation may have begun with construction of the Grand Anicut by the Cholas as early as second century to provide irrigation from the Cauvery River. The entire landscape in the central and southern India is studded with numerous irrigation tanks which have been traced back to many centuries before the beginning of the Christian era. In northern India also there are a number of small canals in the upper valleys of rivers which are very old.

Irrigation during Medieval India

Ghiyasuddin Tughluq (1220-1250) was credited to be the first ruler who encouraged digging canals. Fruz Tughluq (1351-86) was considered to be the greatest canal builder. Irrigation is said to be one of the major reasons for the growth and expansion of the Vijayanagar Empire in southern India in the fifteenth century. Babur, in his memoirs called 'Baburnamah' gave a vivid description of prevalent modes of irrigation practices in India at that time. The Gabar Bunds captured and stored annual runoff from surrounding mountains to be made available to areas under cultivation.



Irrigation Development under British Rule

Close to 19th century according to sources of irrigation; canals irrigation contribution about 45%, wells 35%, tanks 15% and other sources 5%. Famines of 1897-98 and 1899-1900 necessitated British to appoint first irrigation commission in 1901, especially to report on irrigation as a means of protection against famine in India.

Irrigation Development at the Time of Independence

At time of independence net irrigated area of India under British rule which include Bangladesh and Pakistan was 28.2 Mha. After partition net irrigated area in India and Pakistan being 19.4 Mha and 8.8 Mha respectively.

Irrigation Development Plans in India

Post-independence, the Government of India initiated several programs to expand and improve irrigation infrastructure. Key initiatives include:

- Command Area Development and Water Management (CADWM) Programme
- Accelerated Irrigation Benefits Programme (AIBP)
- Bharat Nirman Programme

Types of Irrigation Systems in India

1. Well Irrigation System

Well irrigation is one of the oldest and most widely used methods in India. Different types of wells include shallow wells, deep wells, tube wells and artesian wells. Shallow wells often face water scarcity during dry seasons due to falling water tables, whereas deep wells provide a more reliable water supply throughout the year.

Tube wells, especially those powered by electricity, can irrigate large areas (up to 400 hectares) compared to surface wells. They are widely used in states such as Uttar Pradesh, Punjab, Haryana, Bihar and Gujarat. Artesian wells are also used in regions like Rajasthan and Maharashtra.



2. Tank Irrigation System

In the Deccan, reservoirs are made by constructing dams. This system is greatly adopted in the States of Tamil Nadu, Andhra Pradesh and Karnataka etc. In Northern India also, tanks are constructed for storing water. From all these tanks, water is carried to the fields through canals.

3. Canal Irrigation System

Canal irrigation is one of the most significant forms of irrigation in India and is relatively economical. It is particularly effective in river valley regions and delta areas such as those of the Godavari, Krishna, Kaveri, Mahanadi and Ganga rivers, as well as in the coastal plains of Kerala. States like Uttar Pradesh, Punjab and Haryana are leading users of canal irrigation.

Modern canal systems are integrated with multipurpose river valley projects, serving functions such as irrigation, flood control and power generation.

Types of Canal Irrigation:

A) Inundation Canals

Inundation canals depend on floodwaters from rivers during the rainy season. They do not have permanent regulating structures and are commonly found in states like West Bengal, Bihar and Odisha, as well as in the Brahmaputra valley. These canals are effective only during floods and are less useful during dry seasons.

B) Perennial Canals

Perennial canals provide water throughout the year by drawing from rivers or reservoirs. They are equipped with structures like weirs and sluice gates to regulate water flow. This system ensures consistent irrigation and is widely used in Punjab, Uttar Pradesh and Tamil Nadu. Examples include the Upper Ganga Canal, Sirhind Canal and Buckingham Canal.

Multipurpose River Valley Projects

Multipurpose river valley projects play a vital role in modern irrigation development. These projects provide irrigation, flood control and hydroelectric power generation. Notable examples include:

- Damodar Valley Project (West Bengal)
- Hirakud Project on the Mahanadi (Odisha)



- Kosi Project (Bihar)
- Bhakra Nangal Project (Punjab)

Irrigation projects in India are classified into major, medium and minor categories based on the Cultivable Command Area (CCA). Major projects cover more than 10,000 hectares, medium projects cover 2,000–10,000 hectares and minor projects cover less than 2,000 hectares.

Types of Irrigation Techniques

Surface irrigation:

It involves the movement of water over the land by gravity to wet the soil and allow infiltration. It is one of the oldest and most commonly used irrigation methods. This system includes furrow, border strip and basin irrigation. When water application results in partial or complete flooding of the cultivated field, it is often referred to as flood irrigation.

Localized Irrigation:

It is a modern system in which water is distributed under low pressure through a network of pipes in a controlled and predetermined manner. Water is applied directly to each plant or near its root zone in small quantities. This category includes drip irrigation, micro-sprinkler (spray) irrigation and bubbler systems, all of which aim to improve water use efficiency.

Drip Irrigation:

Drip irrigation, also known as trickle irrigation, delivers water slowly and precisely at or near the root zone of plants. It is considered one of the most efficient irrigation methods because it minimizes water loss through evaporation and runoff. In modern agricultural practices, drip systems are often combined with plastic mulching to further reduce evaporation and are also used for fertigation, allowing fertilizers to be applied directly through the irrigation system.

Sprinkler Irrigation:

Sprinkler irrigation or overhead irrigation, involves distributing water through high-pressure sprinklers or guns placed above the field. These systems may be permanently installed or mounted on movable platforms connected by hoses. Rotating sprinklers, known as rotors, operate through mechanisms such as gear or impact drives. Sprinklers are also used beyond agriculture, including in dust suppression and other industrial applications.



Subsurface Irrigation:

Subsurface irrigation, also known as seepage irrigation, involves supplying water below the soil surface by artificially raising the water table. This method is suitable for areas with high water tables and is often used in lowlands and river valleys, sometimes in combination with drainage systems. It is also widely applied in greenhouse cultivation, where water is supplied from below and excess water is collected and reused.

Benefits of Irrigation Practices

- Enhances food production and ensures food security
- Reduces poverty by increasing agricultural productivity and income
- Generates employment in agriculture and allied sectors
- Promotes equitable water distribution
- Increases cropping intensity and land productivity
- Supports agricultural exports and economic growth
- Provides drought resilience and stabilizes crop yields

Conclusion

Irrigation is a fundamental component of agricultural, social and economic development. It ensures stable food production and acts as a critical input in farming systems. However, it also presents challenges such as soil salinization, environmental degradation and socio-economic disparities. These issues can be addressed through improved water management practices, adoption of efficient technologies and revival of traditional irrigation systems alongside modern infrastructure. A balanced and sustainable approach is essential to ensure long-term agricultural productivity and environmental conservation.

References

- Gaur, A., Biggs, T. W., Gumma, M. K., Parthasaradhi, G., & Turrall, H. (2008). Water scarcity effects on equitable water distribution and land use in a major irrigation project - case study in India. *Journal of irrigation and Drainage Engineering*, 134(1), 26-35.
- Jain, R., Kishore, P., & Singh, D. K. (2019). Irrigation in India: Status, challenges and options. *Journal of Soil and Water Conservation*, 18(4), 354-363.



Majumdar, D. K. (2001). Irrigation water management: principles and practice. PHI Learning Pvt. Ltd.

Reddy, S.R., & Reddy, G.K. (2016). Irrigation Agronomy, Kalyani publishers, New Delhi.

Sikka, A. K., Alam, M. F., & Mandave, V. (2022). Agricultural water management practices to improve the climate resilience of irrigated agriculture in India. *Irrigation and Drainage*, 71, 7-26.





One Farm, Many Benefits: Integrated Farming in India

Harsimar Preet Kour¹, Anupam Soni¹, Irusappan Ilayaraja² and Anoop Kumar³

¹Livestock Production Management Division, NDRI, Karnal, Haryana

²Animal Genetics and Breeding Division, NDRI, Karnal, Haryana

³Animal Reproduction, Gynaecology and Obstetrics Division, NDRI, Karnal, Haryana



INTRODUCTION

Agriculture remains the backbone of India, supporting millions of rural households through crop cultivation, animal husbandry and allied enterprises. However, rising production costs, shrinking land holdings, unpredictable weather and declining soil fertility have reduced the profitability of conventional farming. In this changing scenario, Integrated Farming System (IFS) has emerged as a practical and sustainable approach that helps farmers obtain more income from limited resources. It combines different farm enterprises in a scientific and mutually supportive manner. Through proper planning, the output or waste from one activity becomes an input for another, reducing cost and increasing efficiency.

Meaning of Integrated Farming System

Integrated Farming System refers to the management of multiple farm enterprises such as crops, dairy, poultry, fisheries, horticulture and composting on the same farm in a coordinated way. Instead of depending on a single crop, farmers maintain several interconnected activities that support each other. For example, crop residues may be fed to animals, while dung can be converted into manure or biogas. This integrated arrangement improves productivity its ensures regular cash flow and makes farming more resilient to losses caused by crop failure or market fluctuations.

Need of Integrated Farming in India

The need for IFS is especially high in India because most farmers are small and marginal landholders with limited income opportunities. Dependence on mono-cropping often exposes them to financial risk due to drought, pest attack or unstable market prices. Integrated farming



reduces such risks by creating multiple sources of income from the same land. It also helps families meet their food, fodder and fuel needs within the farm itself. This system is highly useful in areas where farmers need better returns without expanding land area.

Objectives of Integrated Farming

The main objective of IFS is to maximize income and employment from available farm resources while maintaining ecological balance. It aims to produce food, milk, eggs, meat, fruits and vegetables from a single farm unit. Another important goal is to recycle farm waste efficiently so that dependence on outside inputs decreases. The system also promotes soil health, water conservation and sustainable resource use. By integrating enterprises, farmers can ensure year-round income and better livelihood security.

Components of Integrated Farming System

Integrated farming includes several enterprises selected according to climate, market demand and farmer resources. Common components include field crops, vegetables, orchards, dairy animals, Goat rearing, Chicken farming, fish ponds, mushroom units, beekeeping and compost production. Every component plays a specific role in generating income or supplying inputs to another enterprise. The choice of enterprises depends on the size of land, irrigation facilities, labour availability and local opportunities.

Crop Production in IFS

Crop production remains the foundation of most integrated farms. Farmers grow cereals, pulses, oilseeds, vegetables and fodder crops according to local conditions. These crops provide food grains for the family, fodder for livestock and residues for composting or mulching. Inclusion of crop rotation and mixed cropping improves soil fertility and reduces pest incidence. By combining food and fodder crops, farmers maintain both nutritional and livestock requirements.

Dairy Farming in IFS

Dairy farming is one of the most profitable components of integrated farming in India. Cow and Buffalo provide regular daily income through milk sales. Their dung can be used for farmyard manure, vermicompost and biogas generation. Dairy animals also utilize crop residues that might otherwise be wasted. Thus, dairy farming strengthens the economic stability of small farms and supports nutrient recycling.



Goat and Sheep Farming in IFS

Goat and Sheep farming are suitable for dryland, hilly and resource-poor regions. These animals require lower investment than large dairy animals and can survive on shrubs, grazing lands and crop residues. They provide meat, milk, wool and manure. For small farmers, goat and sheep farming acts as a quick source of cash income during emergencies or seasonal needs.

Poultry Farming in IFS

Poultry farming is a fast-return enterprise that fits well into integrated systems. Chicken birds require limited space and can be raised in backyard or semi-commercial units. Eggs and meat provide regular income and family nutrition. Poultry litter is rich in nutrients and can be used in compost pits or fish ponds. Because of short production cycles, poultry helps improve farm liquidity.

Fish Farming in IFS

Fish farming is an important component where water bodies or ponds are available. Freshwater species such as Indian Major Carps can be cultured in farm ponds. Nutrient-rich water from ponds can be used for irrigation, while pond silt can enrich crop fields. Fish farming adds an additional income source and improves protein availability for farm families. It is especially suitable for eastern and coastal states.

Horticulture in IFS

Fruits, vegetables, spices and flowers provide higher returns per unit area than many field crops. Horticulture adds diversity and enhances nutritional security for farm households. Seasonal vegetables can generate frequent cash income, while orchards provide long-term earnings. Kitchen gardens around the house ensure a steady supply of fresh produce. Integration of horticulture with drip irrigation and mulching further improves productivity.

Beekeeping in IFS

Honey Bee keeping is a valuable low-cost enterprise in integrated farming. Bees produce honey, beeswax and other products while improving pollination in crops, vegetables and fruit plants. Better pollination leads to increased yield and quality of produce. Beekeeping requires limited land and can be managed alongside horticulture, mustard cultivation or forest vegetation.



Resource Recycling in IFS

One of the strongest advantages of IFS is efficient recycling of farm resources. Crop residues are fed to livestock, dung is converted into manure, poultry droppings are applied to ponds and pond mud is used in fields. This internal cycling reduces waste and lowers dependence on chemical fertilizers or purchased feed. Resource recycling improves farm sustainability and helps conserve the environment.

Economic Benefits of IFS

Integrated farming creates multiple streams of income throughout the year. A farmer may earn daily from milk, weekly from eggs, monthly from vegetables and seasonally from grain crops. If one enterprise suffers loss, others continue to support household income. This diversification greatly reduces financial risk and increases net returns from the same land area.

Nutritional Benefits of IFS

IFS improves household nutrition because families gain access to cereals, pulses, milk, eggs, fish, fruits and vegetables from their own farms. This balanced food supply reduces dependence on market purchases and improves health, especially among children and women. Availability of diverse foods also supports food security during difficult seasons.

Employment Generation through IFS

Integrated farming requires regular labour for feeding animals, milking, irrigation, harvesting vegetables, pond care and compost management. This creates year-round employment for family members. Women and rural youth can participate in poultry, mushroom cultivation, value addition and direct marketing. Thus, IFS helps reduce seasonal unemployment in villages.

Environmental Benefits of IFS

IFS promotes environmentally friendly agriculture by reducing chemical input use and encouraging organic recycling. Continuous addition of compost and manure improves soil structure and microbial activity. Tree planting and mixed enterprises increase biodiversity. Better water use efficiency and waste management also reduce environmental pollution.



Region-wise Scope of IFS in India

Different regions of India can adopt customized integrated models. Northern plains favor crop-dairy systems, eastern states benefit from rice-fish-duck models, western dry regions suit goat-agroforestry systems, while Himalayan areas are ideal for horticulture-sheep-beekeeping combinations. Region-specific planning increases the success of IFS adoption.

Role of Women in IFS

Women play a central role in integrated farming through milking, feeding animals, kitchen gardening, poultry care, compost preparation and product processing. Many farm enterprises such as backyard poultry and mushroom cultivation are particularly suitable for women-led income generation. Therefore, IFS contributes to women empowerment and family welfare.

Challenges in Adoption of IFS

Despite its benefits, some farmers face difficulties in adopting integrated farming. Lack of technical knowledge, shortage of capital, poor veterinary services, weak market access and water scarcity are common constraints. Small farmers may also hesitate to adopt new enterprises due to fear of failure. Proper training, extension support and cooperative marketing are needed to overcome these barriers.

Government Support for IFS

Several government programs encourage diversified and integrated farming through subsidies, training and credit support. Schemes related to dairy, fisheries, horticulture, organic farming and livestock development help farmers establish integrated units. Access to institutional finance and farmer training centers can significantly accelerate IFS adoption in rural areas.

Future of Integrated Farming in India

The future of IFS is bright because modern technologies are making farming more efficient. Mobile advisory services, drip irrigation, solar pumps, precision livestock tools and online marketing platforms can be combined with traditional integrated systems. Young farmers are increasingly interested in diversified farming models that offer stable income and sustainability.

Conclusion

Integrated Farming System is one of the most practical solutions for improving rural livelihoods in India. It transforms small farms into productive units by linking crops, animals and allied enterprises in a mutually beneficial cycle. The system increases income, provides balanced nutrition, creates employment and conserves natural resources. For the future of Indian agriculture, integrated farming is not only an option but a necessity.



Unlocking the Potential of Underutilized Dryland Fruits

Dr. Swapnil Dnyaneshwar Deshmukh

Assistant Professor

Section of Horticulture P. R. Pote Patil College of Agriculture, Amravati



INTRODUCTION

The practice of cultivating fruit crops in arid and semi-arid regions characterized by low rainfall, high temperatures and limited water resources is generally considered as dryland fruit crops. Dryland cultivation method focuses on conserving water and managing soil efficiently. Underutilized fruit crops, often referred to as minor, neglected or underexploited fruits, represent a rich reservoir of biodiversity with immense potential for nutritional security, sustainable agriculture supporting livelihoods and climate resilience. Underutilized fruits in India, though covering a small area (around 6.56%), show high productivity (over 11 tons/ha). Few underutilized fruits have excellent flavour and very attractive colour, apart from their nutritive and medicinal values. Cultivation of dryland fruit is very restricted and they grow mainly as wild. Being tolerant to biotic and abiotic stresses, these fruit crops are suitable for growing in the drought prone areas. Since India has a rich heritage of indigenous fruit types, some of them have already been recommended for commercial planting. It is apparent that there are more fruit crops that await future exploitation. Semi-arid fruits are the oldest fruit tree crops with wide distribution, reflecting their adaptation to a wide range of edapho-climatic conditions of our country. The understanding of various agro-techniques, propagation methods, canopy management, and biotic and abiotic stresses management are equally important for improving their productivity and quality. It is also called as underutilized fruit crops because of lack of awareness of their nutritional and medicinal values, limited research and development, less-developed consumption habits and market demand and a lack of government policies for their exploitation. Currently the government promotes expansion through programs like MIDH, focusing on high-value indigenous fruits rich in vitamins, fibers, and minerals, vital for combating malnutrition and enhancing farmer income, especially in dry regions like Rajasthan, Maharashtra and MP.



Fruits like Aonla (*Emblica officinalis*), Bael (*Aegle marmelos*), Ber (*Zizyphus jujube*), Chironji (*Buchnanian lanzan*), Custard apple (*Annona squamosa*), Fig (*Ficus carica*), Jackfruit (*Artocarpus heterophyllus*), Jamun (*Syzygium cumini*), Karonda (*Carissa carandas*), Phalsa (*Grewia asiatica*) and Wood apple (*Feronia limonia*) and others are nutritionally dense, offering high levels of vitamins, antioxidants, dietary fiber, and bioactive compounds with therapeutic properties. These fruits have traditionally played significant roles in indigenous diets and medicine but are yet to realize their commercial and economic potential. With increasing awareness of functional foods and sustainable farming, underutilized fruits are gaining recognition for their value in diversifying food systems, enhancing farmers' livelihoods, and conserving agro biodiversity.

Nutritional content :-

Sr. No.	Name of fruit crops	Protein	Fat	Dietary fiber	Carbohydrates	Fructose	Sucrose	Glucose	Vit. C (mg)
1.	Aonla	0.34	0.16	7.75	14.39	2.1	-	1.29	257
2.	Bael fruit	2.63	0.53.7	6.31	28.21	9.58	4.12	2.65	7.5
3.	Ber	1.34	0.35	3.73	9.4	4.3	1.01	2.98	60.93
4.	Custard Apple	1.62	0.67	5.1	20.38	9.1	-	4.25	21.51
5.	Jack fruit	2.74	0.15	3.62	14.01	4.12	4.76	3.33	6.73
6.	Jamun	0.72	0.23	0.9	15.56	-	-	-	18
7.	Karonda	1.15	1.67	7.25	2.87	1.19	-	0.56	135
8.	Manila tamarind	3.56	1.14	4.4	13.54	3.45	4.56	4.12	55.78
9.	Phalsa	1.66	0.14	4.54	15.09	6.12	2.22	4.66	5.11
10.	Tamarind	2.92	0.15	5.31	67.35	12.31	26.04	14.53	3.62
11.	Wood Apple	3.14	3.62	5.21	9.4	1.38	1.02	1.41	22.17

All the units are in g per 100 g of edible fruits.

Importance of dryland fruit crops:-

- Provide variety of products that include food, fodder, fuel wood, gums, resins, fibre, medicine etc.



- These crops are adaptable for different climatic zones and changes in weather conditions.
- Most of them are very rich sources of vitamins-A, B1, B2, B3, B6, B9, B12, C, minerals- Ca, P, Fe, folic acid, dietary fiber and other nutrients such as carbohydrates, proteins, fats and nutraceuticals
- Cheap and readily available.
- Vital source of genes against biotic and abiotic stresses.
- Low input requiring crops.
- Produce higher biomass than field crops per unit area resulting in efficient utilization of natural resources.
- Can help achieving ecological security through improvement of wastelands by preventing soil erosion, improving fertility of soil and promoting biodiversity.
- These crops have many advantages like easier to grow and hardy in nature, producing a crop even under adverse soil and climatic conditions.
- The underutilized crops have the potential to give economic security by giving employment and by fetching good returns from their sale in raw form as well as value added products.
- Usage of marginal and wastelands for agricultural purposes to meet the ever increasing food demand

Constraints in cultivation of dryland fruit crops:-

- Lack of technical information, marketing network and infrastructure facility.
- Lack of national policy and credit and investment.
- Lack of interest by researchers, agriculturists and extension workers
- Lack of producer interest and limited germplasm available.
- Lack of knowledge about suitable postharvest management practices.
- Less emphasis in researches for exploitation of potential underutilized fruits.



- Lack of information about the economic benefits.

Dryland fruit crops seen in India

Aonla (*Emblica officinalis*)

It is also called as Indian gooseberry and indigenous to Indian sub-continent. India ranks first in the world in area and production of this crop. It is a deciduous fruiting plant and second richest natural source of vitamin C (ascorbic acid) having approximately 600 to 700 mg per fruit which makes its wide use in Ayurveda medicine.

- Extremely rich in Vitamin C, strengthening the immune system and fighting infections.
- High fiber content aids digestion, relieves constipation, and cleanses the gut.
- Helps lower cholesterol (LDL, triglycerides) and strengthen heart muscles.
- Vitamin C promotes collagen, improving skin quality, while it nourishes hair, potentially reducing hair loss and promoting growth.
- Neutralizes free radicals, reduces inflammation, and protects against cellular damage.
- Helps manage diabetes by improving insulin sensitivity.
- May protect the liver and support kidney function.
- Antioxidants help delay the aging process.
- Juice mixed with honey or candy offers relief from coughs and colds.

It is consumed as Raw fruit, juice, powder (churna), candy, supari, chyawanprash or as murabba (with jaggery) and also as a hair pack or serum.

Bael (*Aegle marmelos*)

It is an important indigenous fruit crop and member of citrus family Rutaceae. Grows wild in sub-mountainous regions of south east Asia including India, Pakistan, Sri Lanka, Bangladesh and Thailand. In India, bael is grown in tropical to subtropical regions including hot arid regions.

- High fiber content helps with both constipation (unripe fruit) and diarrhea (ripe fruit/pulp).
- Tannins reduce gut inflammation, fighting ulcers and indigestion.



- Rich in Vitamin C and antioxidants which boosts immunity.
- Antimicrobial and antifungal properties help combat various infections.
- Helps control blood sugar levels.
- Potassium and antioxidants help lower cholesterol and regulate blood pressure.
- Reduces inflammation in airways, easing asthma, bronchitis, and coughs.
- Antioxidants improve skin texture; leaves help with dandruff, itching, and hair health.
- Cleanses liver and kidneys, flushing out toxins.
- Calming properties help reduce stress.
- Good source of iron, helping with anemia.

A variety of processed product like squash, ready to serve drinks, preserve like jam jelly, candy *etc.* can be prepared out of bael fruit pulp.

Ber (*Zyziphus mauritiana*)

It is also called as Indian Jujube belongs to the family Rhamnaceae an ideal fruit tree for arid and semi-arid regions in tropical and subtropical climate. Fruits are greenish yellow to reddish brown. It has a high amount of vitamin C (85-95 mg per 100 g).

- High fiber content aids smooth bowel movements and prevents constipation.
- Rich in Vitamin C, it strengthens the immune system and helps fight infections.
- Potassium helps regulate blood pressure and relax blood vessels.
- Contains compounds (saponins, flavonoids) that promote calmness and better sleep.
- Antioxidants and Vitamin C protect skin cells, fight signs of aging, and promote collagen.
- Low glycemic index helps regulate glucose levels, beneficial for diabetes management.
- Low calorie, high fiber, and filling, making it great for appetite control.
- Contains calcium and phosphorus for healthy bones.



- Natural sugars provide energy, while antioxidants protect brain cells, enhancing memory.
- Antibacterial and anti-inflammatory properties can speed up wound healing.

It is consumed as a healthy snack, powder called as borkut or candy.

Chironji (*Buchnanania lanzan*)

It is indigenous, medium sized tree, with straight, cylindrical trunk, up to 10-15 m height and tomentose branches. Being a vulnerable medicinal plant, is included in the Red Data Book published by International Union for Conservation of Nature and Natural Resources. Chironji seeds are rich in nutrients, medicinal properties and is an active source of phenolics, natural antioxidants, fatty acids and minerals.

- Rich in antioxidants and vitamins, it strengthens the immune system and fights infections.
- Antioxidants improve complexion, reduce acne, soothe inflammation, and provide a natural glow.
- Dietary fiber helps with constipation and improves gut health.
- Healthy fats and antihyperlipidemic properties support healthy cholesterol levels and reduce heart disease risk.
- Proteins and healthy fats provide sustained energy, combating fatigue.
- Contains calcium and phosphorus, crucial for strong bones.
- Its cooling properties help reduce body heat, making it great for summer.
- Can help alleviate coughs, colds, and asthma symptoms.
- Helps in managing blood sugar levels.
- Assists in purifying blood and improving liver function.

It is used as culinary add to desserts (kheer, halwa), curries, smoothies, or eat as a snack. Powdered form used in face packs for skin glow; oil applied for hair/skin issues. Used for various ailments, often with its cooling properties for Pitta-related issues.

**Custard apple (*Annona squamosa*)**

It is a sweet, creamy tropical fruit with white flesh, large black seeds, and a scaly green exterior, known as sitaphal or sharifa in India, prized for its rich, vanilla-like flavor and eaten fresh or in desserts, offering vitamins C & B6 and fiber.

- It is an excellent source of energy, due to its high carbohydrate content.
- Consuming this fruit can provide an instant energy boost,
- The natural sugars present in custard apple ensure sustained energy release, keeping you active and alert.
- Despite its sweetness, custard apple can be beneficial for people with diabetes. As it has a low glycemic index, it releases sugars slowly into the bloodstream.
- The fibre content helps in regulating blood sugar by slowing down the absorption of glucose.
- The anti-inflammatory and antimicrobial properties of custard apple make it effective in treating various skin infections.
- Rich in potassium and magnesium, two minerals crucial for heart health. Potassium helps in regulating blood pressure by balancing the sodium levels, while magnesium aids in maintaining a regular heartbeat and helps in preventing arrhythmias.
- Contains antioxidants like flavonoids, which help in neutralizing the harmful free radicals in the body.
- Vitamin A helps in improving the vision and preventing age-related macular degeneration, while vitamin C protects the eyes from oxidative damage.
- The high levels of B vitamins in custard apple, particularly vitamin B6, play a crucial role in brain health. Vitamin B6 helps in the production of neurotransmitters like serotonin and dopamine, which regulate mood and cognitive function.

It is consumed as table fruit, blend into smoothies, milkshakes, or add to desserts.

***Fig (Ficus carica)***

Fig was an important food crop since ancient civilization. It is a highly nutritious fruit consisting of 84% pulp and 16% skin. Besides, the fruit also contains protein, calcium, iron, vitamin A and thiamine at varying concentrations.

- High fiber promotes regularity and relieves constipation, while probiotics support gut health.
- Potassium helps balance sodium for blood pressure control; fiber and antioxidants lower bad cholesterol.
- Good source of calcium, magnesium, and potassium, crucial for bone density and preventing osteoporosis.
- Fiber keeps you feeling full longer, aiding in appetite control and weight loss.
- Rich in antioxidants (polyphenols) and nutrients that fight free radicals and strengthen the immune system.
- Supports blood sugar management and provides energy.
- Can help exfoliate, moisturize, brighten skin, and fight blemishes.
- Iron content supports ovulation, and figs have been linked to menstrual cycle health.
- Some studies suggest potential benefits for memory and anxiety reduction.

It is consumed fresh or dried as a snack, added to salads, smoothies, or oatmeal. Use in baked goods or pair with cheese and soak dried figs overnight for easier digestion and enhanced benefits.

Jackfruit (Artocarpus heterophyllus)

It is a largest tree born tropical fruit in the world belongs to the family Moraceae. It is a monoecious evergreen tree, cauliflorous, indigenous to the rain forests of the Western Ghats in the south-western parts of India.

- High in Vitamin C, it boosts white blood cell production to fight infections.
- A good source of dietary fiber, preventing constipation and promoting gut health.



- Potassium helps regulate blood pressure, while fiber and antioxidants reduce heart disease risk.
- Low glycemic index and high fiber help stabilize blood sugar, beneficial for diabetics.
- Antioxidants like Vitamin C and flavonoids protect skin, reduce aging signs, and promote hair strength.
- Contains calcium, potassium, magnesium, and Vitamin K for better bone density and metabolism.
- Contains flavonoids, carotenoids, and phytonutrients that combat free radicals and chronic diseases like cancer.

It is consumed as a sweet snack (ripe fruit), in savory dishes, as a meat substitute.

Karonda (*Carissa carandas*)

A fruit of dry land which is a widely grown indigenous shrub in India and is able to flourish in marginal and waste land where other crops of commercial importance are unsuitable. Also known as 'Christ Thorn Tree' is a hardy, evergreen, spiny and indigenous shrub widely grown in India.

- High Vitamin C content strengthens the immune system and helps fight infections.
- Fiber aids digestion, prevents constipation, and supports a healthy gut.
- Antioxidants, potassium, and fiber help lower bad cholesterol (LDL) and blood pressure, reducing heart disease risk. Its low glycemic index and phytonutrients help manage diabetes.
- Fights free radicals, reducing oxidative stress and inflammation.
- Antimicrobial and antioxidant properties benefit skin by fighting infections, reducing blemishes, and promoting glow.
- Iron content helps prevent iron deficiency anemia.
- Contains calcium, essential for strong bones.
- May help with stress and bring down fever.

It is consumed as fresh fruit, jam, jelly pickle and also used as a live fence to protect from animals.

**Wood apple (*Feronia limonia*)**

It is drought hardy fruit native from India and belongs to citrus family Rutaceae. The tree is semi spreading to erect in growth habit and produces nutritive acidic fruit with very high yield potential. The fruit pulp is creamy white when unripe but becomes brownish with pleasant aroma upon ripening.

- High fiber, tannins, and natural laxatives help regulate bowel movements, prevent constipation, and cleanse the digestive tract.
- Rich in Vitamin C, antioxidants, zinc, and iron, it strengthens the immune system.
- Its low glycemic index helps slow sugar absorption, beneficial for diabetes management.
- Potassium content helps regulate blood pressure, and antioxidants reduce bad cholesterol.
- Contains tannins and other compounds that reduce inflammation, helping with skin issues and internal irritation like stomach ulcers.
- High water content and natural compounds help cool the body, making it ideal for summer.
- Used in Ayurveda to treat cough, asthma, and bronchitis.
- Helps cleanse the liver and kidneys.
- Can help with constipation during pregnancy.

It is consumed fresh, preserve like jelly, pickle, syrup etc.



Digital Soil Mapping

**Kamalesh Kanna Shanmuganathan^{1*}, Karthikkumar A², Manikandan S³,
Arunpandi P¹, Barathraj D¹**

^{1*}PhD Scholar, Department of Remote Sensing and GIS, Tamil Nadu Agricultural University, Coimbatore – 641003

²Young professional, ICAR- Sugarcane Breeding Institute, Coimbatore - 641007

³Young professional, ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur — 440033



INTRODUCTION

SOIL (Soul of Infinite Life) is the great life-supporting system for human beings from the beginning of civilisation. A detailed study of soil is required for command area development, sustainable agriculture, watershed management, soil conservation, reclamation of degraded lands, etc. So, mapping (Conventional soil mapping) of soils through field investigation and laboratory studies provides a detailed description, identification and delineation of different kinds of soils that are spatially available.

By combining this traditional conventional soil mapping (field investigation and laboratory) with modern computer technologies like Geographic Information System (GIS), remote sensing, Machine Learning (ML) and Deep Learning (DL), we can produce high-resolution spatially interpolated soil inference systems that support decision makers, research workers, farmers, etc., called Digital Soil Mapping (DSM).

DSM or ‘predictive soil mapping’ or ‘pedometric mapping’ is the method of creating and populating spatial soil information by means of field and laboratory observations, geo-statistical models, machine learning and deep learning techniques. It produces detailed information about varying soil properties such as pH, soil moisture, Soil Organic carbon (SOC), Electrical Conductivity (EC), Cation Exchange Capacity (CEC) and nutrient details such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S) etc. with the help of spatially available environmental covariates like Digital Elevation Model (DEM), indices derived from satellite data and ancillary data (parent material). DSM is an advanced technology for mapping soil properties or soil classes, secondary soil properties and soil functions or threats.



Principle of Digital Soil Mapping (DSM)

The underground principle of DSM is referred to as the 'SCORPAN' principle. Where SCORPAN is the modified form of soil forming factors 'clorpt'.

$$S = f(S, C, O, R, P, A, N) + e$$

Where, S: Soil properties or prior knowledge or other properties of soil at a point

f: machine learning and deep learning models

C: climate and its models

O: organism, vegetation, fauna or human activities

R: topography, relief, landscape-related details

P: parent material and other related information

A: age and time factor

N: space, relative spatial information

e: auto-correlated random spatial variation

Thus, the equation states that soil(S) at an unsampled site is the random function of SCORPAN factors.

Environmental Covariates

Environmental Covariates are measurable environmental variables that represent the soil-forming factors (SCORPAN) and help explain the spatial variation of soil properties across a landscape. They are spatially continuous data layers derived from remote sensing, DEMs, climate models, geology, and land use maps, and are used as predictors in machine learning and geostatistical models for DSM. A list of available environmental covariates is given in Table 1.

Characteristics of Environmental Covariates

- Continuous spatial features
- Quantifiable and reproducible
- Derived from physically meaningful processes



- Scientifically linked to soil formation
- High-resolution and up to date
- Available over large regions
- Machine-learning friendly (numeric, raster, standardised)

Table 1. Environmental covariates

Parameter	Description
Organism (O)	
Satellite band data	Satellite band data represents reflectance captured in specific wavelength regions (visible, NIR, SWIR, thermal) by remote sensing sensors, highlighting unique surface characteristics. These raw spectral values act as key inputs in DSM for deriving indices and predicting soil properties.
Land Use & Land Cover	Land Use & Land Cover represents natural and human-made surface features, differentiating categories like forests, agriculture, water bodies, and urban areas.
Normalised Difference Vegetative Index (NDVI)	NDVI is a vegetation index that measures plant greenness and biomass by comparing the reflectance difference between the NIR and Red spectral bands. $NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$
Relief (R)	
Closed Depressions	Closed Depressions map low-lying DEM (Digital Elevation Model) areas where water accumulates due to the absence of natural outlets.
Convergence Index (CI)	CI quantifies terrain convergence or divergence in a DEM, indicating zones where water and materials accumulate (positive CI) or disperse (negative CI).
Elevation	Elevation is the vertical height of the terrain surface derived from DEMs using remote sensing methods like LiDAR, radar, or satellite imagery.
LS- Factor	LS-Factor combines slope length (L) and slope steepness (S) from the RUSLE model to estimate topographic influence on soil erosion.



Slope	Slope represents the rate of terrain inclination derived from DEMs, influencing runoff, erosion, drainage, and soil formation processes.
Hill shade	Hillshade simulates illumination on a DEM surface, highlighting terrain shadows and sunlight effects for visualising landform variations.
Aspect	Aspect indicates the compass direction a slope faces, affecting sunlight exposure, wind flow, and microclimatic conditions.
Curvature	Curvature describes whether terrain is convex, concave, or flat, helping interpret water flow, erosion risk, and deposition zones.
Climate (C)	
Mean Annual Rainfall	Total average precipitation received at a location over a year, calculated as the sum of monthly precipitation values across 12 months.
Mean Annual Temperature	Average temperature of a location over an entire year, typically calculated as the mean of monthly temperatures.
Parent material (P)	
Carbonate Difference Ratio	Particularly effective for identifying calcareous soils and determining the soil's buffering capacity, which influences nutrient availability and soil health. $\rho_{Red} - \rho_{Green} / \rho_{Red} + \rho_{Green}$
Clay Difference Ratio	Identify the degree of clay buildup or depletion, which can indicate soil formation processes like clay translocation, weathering intensity, or horizon development. $\rho_{SWIR(a)} - \rho_{SWIR(b)} / \rho_{SWIR(a)} + \rho_{SWIR(b)}$
Geomorphology	Information about the evolution of the Earth's surface during the geological period.
Iron Difference Ratio	Assess the difference in iron concentrations within soils or rocks. $\rho_{Red} - \rho_{SWIR(a)} / \rho_{Red} + \rho_{SWIR(b)}$
Lithology	Lithology describes the physical and chemical characteristics of rocks—such as mineral composition, texture, and structure—that influence soil parent material.



Physiography	Physiography characterises landscape features and terrain patterns shaped by geological, hydrological, and geomorphic processes that determine soil distribution.
---------------------	---

DSM methods and techniques

DSM is carried out mainly in three methods, namely regression model, geostatistical techniques and machine learning. Whereas other methods involve deep learning, hybrid models, ensemble techniques, cloud-based DSM, Bayesian modelling, etc.

a. Regression models

Regression models quantify the relationship between soil properties (dependent variables) and environmental covariates (independent variables). When the relationship is linear, models like Linear Regression and Multiple Linear Regression are applied for spatial prediction. Advanced forms such as Geographically Weighted Regression (GWR) and non-linear regressions capture spatially varying or complex soil–environment interactions.

b. Geostatistical Techniques

Geostatistics relies on spatial autocorrelation, quantified through variogram models, to estimate soil variability. Interpolation methods such as Kriging, Co-kriging, and Regression Kriging predict soil properties at unsampled locations. These techniques also provide uncertainty estimation, making them powerful for spatially explicit soil modelling.

c. Machine Learning

Machine Learning models (like Random Forest, Support Vector Machines, Neural Networks) learn non-linear relationships from large spatial datasets. They integrate diverse inputs such as remote sensing, terrain attributes, climate data, and vegetation indices for robust soil prediction. Modern ML approaches, including Deep Learning, Ensemble Modelling, and Cloud Computing workflows, greatly enhance accuracy in DSM.



Water Hyacinth (*Eichhornia crassipes*): From Invasive Weed to Valuable Bio-Resource

Tanuja S^{1*}, Binsi P.K², Ankita Sahu¹, P. R. Sahoo³ and B.B. Jena¹

¹ICAR-Central Institute for Women in Agriculture, Bhubaneswar

²ICAR-Central institute of Fisheries Technology, Kochi, Kerala

³ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar



INTRODUCTION

Aquatic weeds are a serious and expanding ecological challenge in India. Of the nearly 160 aquatic weed species reported in the country, about ten are considered particularly problematic: *Eichhornia crassipes* (water hyacinth), *Salvinia molesta* (water fern), *Nymphaea stellata*, *Nelumbo nucifera*, *Hydrilla verticillata*, *Vallisneria spiralis*, *Typha angustata*, *Chara* spp., *Nitella* spp., and *Ipomoea* spp. Among these, five species—*Eichhornia crassipes*, *Salvinia molesta*, *Hydrilla verticillata*, *Alternanthera philoxeroides* (alligator weed), and *Pistia stratiotes* (water lettuce)—are recognized globally as some of the world's worst aquatic weeds and hold similar status in India.

Extent of Water Hyacinth Infestation in India

Among the invasive aquatic plants, water hyacinth is the most widespread and destructive weed. In states such as Assam, West Bengal, Odisha, and Bihar, it is estimated to have invaded nearly 40% of the water surface area in certain regions. Overall, approximately 20–25% of the total utilizable water bodies in India are currently infested with water hyacinth. Native to tropical South America, water hyacinth was introduced into India in 1896 as an ornamental plant (Kumar and Pradhan, 2018). Since then, it has proliferated across freshwater lakes, rivers, irrigation channels, ponds, and streams throughout the country. Water hyacinth reproduces via seed, with one plant capable of producing up to 5000 seeds. These seeds can sink to the bottom of the water, thus ensuring their survival for 20 years. Its extraordinary vegetative reproduction capacity and adaptability to diverse environmental conditions have facilitated its rapid and uncontrolled spread.



Environmental Hazards Posed by Water Hyacinth

The unchecked growth of aquatic weeds leads to severe ecological and socio-economic consequences. Dense mats formed by these plants obstruct sunlight penetration, significantly reducing photosynthesis in submerged aquatic vegetation. This results in lower dissolved oxygen levels, adversely affecting fish and other aquatic fauna. The restricted diffusion of light and oxygen disrupts the ecological balance, causing drastic changes in plant and animal communities. Further, aquatic weeds impede water movement, contributing to sediment accumulation and eutrophication. They clog irrigation canals, hydropower intakes, and drinking water supply channels, thereby affecting agricultural productivity and energy generation. Navigation and water transport are also hampered due to blocked waterways. Thus, aquatic weed infestation not only degrades water quality but also threatens livelihoods dependent on aquatic ecosystems.

Chemical Composition of Water Hyacinth

Understanding the chemical composition of water hyacinth is essential for exploring its potential utilization. Various studies have reported differences in composition depending on environmental conditions and analytical methods (Akinwade et al, 2013; Varanasi et al, 2017; Sukarni et al, 2019). Broadly, water hyacinth biomass contains significant proportions of structural carbohydrates and nutrients:

- Hemicellulose: Approximately 30–33%
- Cellulose: Around 19–25%
- Lignin: Ranges from 5.6–16%
- Crude Protein: About 10–20%
- Carbon: 14–38%
- Nitrogen: Around 2.8–2.9%
- Oxygen: 28–49%
- Hydrogen: About 5.8–6.2%

It also contains appreciable amounts of essential macronutrients and micronutrients such as phosphorus, calcium, magnesium, potassium, sodium, and sulphur.



Potential Uses of Water Hyacinth

Efforts to eradicate water hyacinths involve the use of machines, chemical herbicides, or biological approaches such as using insects or plant diseases. However, this disposal method is expensive and has negative impacts on aquatic ecosystems, such as damage to beneficial aquatic plants and water pollution. Therefore, using water hyacinth for other purposes is an environmentally friendly way to reduce its number. Numerous studies have investigated the potential applications of aquatic weeds, particularly water hyacinth. These include:

Phytoremediation

Phytoremediation uses plants for cleaning up of soil or water so that either is free from both organic and inorganic impurities. Water hyacinth can be a suitable candidate for bioremediation and under controlled growth conditions can be an efficient and economical substitute to conventional cleanup methods as it speeds up the extraction and absorption of industrial and agricultural effluents contaminated with organic, inorganic, and toxic metals. Water hyacinth is capable of treating wastewater containing heavy metals and dissolved ions. The leaves, roots, and bulb tissues of the plant exhibit hyper accumulation abilities for heavy metals. Studies have demonstrated that water hyacinth can remove up to 99.5% of hexavalent chromium (Cr VI) within 15 days. It also significantly reduces Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and turbidity (Saha et al., 2017).

Biofuel Production

The comparatively lower lignin content present in water hyacinth makes the plant a great choice when sourcing for biomass, as cellulose and hemicellulose are converted with ease to sugar that is fermentable, resulting in great quantities of biomass that can be exploited in the biofuel industry (Bhattacharya and Kumar, 2010). Biodiesel production using potassium hydroxide extracts from water hyacinth has been reported. Comparative studies have shown that biomass from water hyacinth and water lettuce can produce bioethanol yields comparable to conventional agricultural residues such as wheat straw and cotton gin waste.

Animal Feed component

The dry matter of water hyacinth contains high protein and mineral content, making it a useful source of animal feed and roughage. The presence of some important phytochemicals such as alkaloids and saponins has been reported in water hyacinth, suggesting that they can be considered as good feed supplement (Su et al., 2018).



Fish Feed

Fishes have different feeding habits and some species such as tilapia and grass carp can feed on several aquatic plants. Hence, water hyacinth can be used as a raw material in formulating fish feed. This may increase the crude protein level of the feed (due to the high protein content in the leaves and roots of the plant) and possibly in digesting the feed better.

Biogas Production

Biogas is the product of fermentation of organic materials in the absence of oxygen using microorganisms. Water hyacinth can be useful in the production of biogas because it possesses a high amount of hemicellulose contents (Nugruha et al., 2018). Attention is now being drawn toward the production of biogas as a source of fuel due to its cleanliness and cost. About three liters of biogas was reported to be produced when 2.5 kg of dried biomass of water hyacinth was mixed with cow dung and poultry droppings in the ratio 2 : 2 : 1 when the potential of water hyacinth to produce biogas was studied. Methane and carbon dioxide were produced up to 62% and 34%, respectively (Fadairo and Fagbenle, 2014).

Organic Fertilizer and Compost

Among all utilization pathways, compost production is considered one of the most cost-effective and environmentally sustainable management strategies. Composting not only reduces the volume of invasive biomass but also transforms it into nutrient-rich organic manure. The lack of sufficient organic material is often a major constraint in compost production. In this context, water hyacinth serves as a promising alternative organic resource. Composting followed by soil application is widely regarded as an efficient disposal and nutrient recycling strategy.

Water hyacinth compost is rich in carbon and essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) (Balasubramanian et al., 2013; Mazumder et al., 2021). Studies have demonstrated that it can outperform town compost and farmyard manure in terms of nutrient content, including N, P₂O₅, K₂O, and C:N ratio (Begum et al., 2022). Its application enhances soil fertility, improves soil structure, and increases crop productivity. Additionally, its slightly alkaline pH (around 8) makes it particularly useful for stabilizing acidic soils. The relatively low lignin content and moderate cellulose levels make it suitable for biological degradation processes such as composting and biofuel production. Notably, water hyacinth can accumulate up to 3.2% nitrogen in its dry mass, and its carbon-to-nitrogen (C:N) ratio generally



ranges between 8:1 and 15:1 (Khan and Sarwar, 2002; Gunnarsson and Petersen, 2007). This relatively narrow C:N ratio is advantageous for composting, as it promotes rapid microbial activity and efficient decomposition.

Vermicomposting further enhances its nutrient profile. Vermicompost derived from water hyacinth has been reported to contain up to, 47% more nitrogen, 60% more phosphorus, 40% more potassium compared to ordinary compost (Ogutu 2019). Such nutrient enrichment significantly improves plant growth and yield. Application of water hyacinth compost has shown positive effects on various crops, including tomato and peanut (*Arachis hypogaea* L.). Studies indicate improved growth rate, yield, and soil properties without harmful heavy metal accumulation in edible plant parts. Furthermore, integrated application of water hyacinth compost with mineral fertilizers produces superior soil characteristics and crop yields compared to sole applications Gezahegn et al (2024). Water hyacinth compost also contributes to combating soil organic matter decline and reducing soil erosion. Foliar sprays derived from aquatic weeds are being explored as promising inputs for drip irrigation systems and hydroponic cultivation.

Several composting and vermicomposting techniques have been developed using water hyacinth in combination with other organic residues:

- **Heap Method:** Combined with food waste, poultry litter, wood chips, cow dung, grain straw, rice straw, soil, and ash in varying proportions.
- **Vermicomposting:** Mixed with cow dung (ratios ranging from 3:1 to 10:1), paddy straw, and inoculated with earthworms.
- **Agitated Pile Composting:** Water hyacinth blended with cattle manure and sawdust (6:3:1).
- **Aerobic Composting:** Mixed with banana residue and cow dung.
- **Microbial Decomposition:** Inoculated with specific microbial consortia to accelerate breakdown.

The choice of method and combination significantly influences compost quality. Nutrient enrichment, moisture balance, aeration, and microbial activity determine the final compost characteristics. Importantly, the nutritional value of vermicompost depends largely on the type and proportion of raw materials used. Appropriate nutrient sources for earthworms, along with



optimal mixture ratios, enhance worm growth, reproduction, and metabolic efficiency. This, in turn, produces high-quality vermicompost rich in plant-available nutrients.

Livelihood and Industrial Opportunities

Beyond agricultural use, water hyacinth has emerging industrial and livelihood applications. Technologies are being developed to convert its fibers into paper and paperboard. In regions near the Harike Wildlife Sanctuary, villagers have successfully transformed the plant into handicrafts, generating supplementary income (Bose 2019). In Assam, the government implemented a two-year project (2017–2019) under the Assam State Rural Livelihood Mission to promote water hyacinth-based commercial products and sustainable livelihoods. The initiative supported rural communities in producing crafts and value-added products from the invasive weed, demonstrating how ecological challenges can be converted into economic opportunities (Pendse and Dsehmukh, 2024)

Conclusion

Aquatic weeds, particularly water hyacinth, pose serious environmental and economic challenges in India. Their rapid proliferation degrades water quality, disrupts aquatic ecosystems, and obstructs irrigation and water supply systems. However, their substantial biomass and nutrient-rich composition present significant opportunities for resource recovery. Among various utilization pathways, composting and vermicomposting stand out as sustainable, cost-effective solutions. These methods not only manage invasive biomass but also enhance soil fertility, improve crop productivity, and contribute to sustainable agriculture. Furthermore, industrial applications such as paper production and handicrafts create livelihood opportunities for rural communities. Thus, transforming water hyacinth from an ecological menace into a valuable bioresource represents an integrated approach combining environmental management, soil health restoration, renewable energy exploration, and rural livelihood enhancement.

References

- Akinwande, V.O., A.A. Mako, O.J. Babayemii. 2013. Biomass yield, chemical composition and the feed potential of water hyacinth (*Eichhornia crassipes*, Mart. Solms-Laubach) in Nigeria. *International Journal of Agricultural Sciences*. 3 (8): 659-666.
- Balasubramanian, D., Arunachalam, K., Arunachalam, A. and Das, A.K. (2013). Effect of water hyacinth (*Eichhornia crassipes*) mulch on soil microbial properties in lowland rainfed



- rice-based agricultural system in northeast India. *Agricultural Research*.2(3): 246-257.
DOI 10.1007/s40003-013-0073-7.
- Begum Rasmiya S.L., Himaya S.M.M.S., Afreen S.M.M.S. 2022. Potential of Water Hyacinth (*Eichhornia crassipes*) as Compost and its Effect on Soil and Plant Properties: A Review . *Agricultural Reviews*. 43(1): 20-28. doi: 10.18805/ag.R-184.
- Bhattacharya, A. and Kumar, P. 2010. Water hyacinth as a potential biofuel crop. *Electronic Journal of Environmental, Agricultural and Food chemistry*. 9(1): 112-122
- Bose. A. 2019. <https://researchmatters.in/sciqs/water-hyacinth-invasion-good-intent>
- Fadairo A. A., Fagbenle R. O. 2014. Biogas production from water hyacinth blends. *Proceedings of the 10th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics*; July 2014; Orlando, FL, USA
- Gezahegn, A., Selassie, Y.G., Agegnehu, G., Addisu, S., Mihretie, F.A., Kohira, Y., Lewoyehu, M. and Sato, S. 2024. Sustainable weed management and soil enrichment with water hyacinth composting and mineral fertilizer integration. *Environmental Challenges* 16: 101007
- Gunnarsson, C.C. and Petersen, C.M. (2007). Water Hyacinths as a resource in agriculture and energy production: A Literature Review. *Waste Management*. 27: 117-129. <http://dx.doi.org/10.1016/j.wasman.2005.12.011>.
- Khan, S. and Sarwar, K.S. (2002). Effect of water-hyacinth compost on physical, physico-chemical properties of soil and on rice yield. *Journal of Agronomy*. 1: 64-65. <http://dx.doi.org/10.3923/ja.2002.64.65>.
- Kumar, S and Pradhan. A 2018 Aquatic weeds problems in India — Challenge for management. *Indian farming*. 68(11): 42-45
- Mazumder, P. A., Jyoti P, M., Khwairakpam, U. Mishra, A.S. Kalamdhad. 2021. Enhancement of soil physico-chemical properties post compost application: optimization using Response Surface Methodology comprehending Central Composite Design. *Journal of Environmental Management* 289: 112461, 10.1016/j.jenvman.2021.112461
- Nugraha W. D., Syafrudin, Pradita L. L., Matin H. H. A., Yono B. Biogas production from water hyacinth (*Eichhornia crassipes*): the effect of F/M ratio. *IOP Conference Series: Earth and Environmental Science*. 2018;150 doi: 10.1088/1755-1315/150/1/012019)



- Ogutu, P.A. 2019. Vermicomposting Water Hyacinth: Turning Fisherman's Nightmare into Farmer's Fortune. International Journal of Research and Innovation in Applied Science (IJRIAS). 4(1): 12-14.
- Pendse, D.S. and Deshmukh, M.P. 2024. Materials Today: Proceedings, <https://doi.org/10.1016/j.matpr.2023.12.047>
- Saha, P., Shinde, O. and Sarkar, S. 2017) Phytoremediation of industrial mines wastewater using water hyacinth. International Journal of Phytoremediation. 19(1): 87–96. <https://doi.org/10.1080/15226514.2016.1216078>
- Su W., Sun Q., Xia M., Wen Z., Yao Z. 2018. The resource utilization of water hyacinth (Eichhornia Crassipes [mart.] solms) and its challenges. Resources, 7(3):p. 46. doi: 10.3390/resources7030046.
- Sukarni, S., Yahya Z., Sumarli S., Retno W., Avita, A .P. and Suhermanto, M 2019. Physical and Chemical Properties of Water Hyacinth (Eichhornia crassipes) as a Sustainable Biofuel Feedstock. IOP Conference Series. Material Science and Engineering. 515: 012070. DOI 10.1088/1757-899X/515/1/012070
- Varanasi, J.L, Sinha, P., Das, D., 2017. Maximizing power generation from dark fermentation effluents in microbial fuel cell by selective enrichment of exoelectrogens and optimization of anodic operational parameters. Biotechnology Letters. 39(5):721e30.



Role of Artificial Intelligence in Preventing Germplasm Dilution of Indigenous Dairy Animals

Taniya Qamar¹, Indu Devi¹, Jaya Qamar², Amrita Gupta¹ and Deeksha Patel¹

¹Livestock Production Management Division, NDRI, Karnal, Haryana

²Livestock Production Management Division, IVRI, Izzatnagar, U.P.



INTRODUCTION

Livestock rearing is one of the major sources of livelihood for over 70% of rural household of India, with significant proportion being small and marginal farmers landless labourers and significantly contributes to the national economy. This sunrise sector provides employment to about 80 million people across India. Total bovine population of India is 303.76 million and India has acknowledged 55 indigenous breeds of cattle and 22 indigenous breeds of buffalo. Indigenous dairy animal breeds play a pivotal role in ensuring sustainable livestock production, particularly in developing countries with diverse agro-climatic conditions. These breeds possess unique traits such as heat tolerance, disease resistance, feed efficiency, longevity and reproductive robustness. Despite comparatively lower milk yield than exotic breeds, their overall productivity under low-input systems makes them indispensable for small and marginal farmers.

In recent decades, artificial insemination (AI) has emerged as a powerful reproductive biotechnology for genetic improvement and dissemination of superior germplasm. While AI has successfully enhanced milk production and reproductive efficiency, its indiscriminate and unregulated use has contributed to genetic erosion of indigenous breeds. Although exotic crossbreeding has been widely acknowledged as a cause of germplasm dilution, mixing of one indigenous breed with another indigenous breed through uncontrolled AI programs has received limited attention.

The absence of accurate breed identification, inadequate record-keeping, and limited farmer awareness have resulted in the emergence of non-descript populations with diluted genetic



identity. In this context, artificial intelligence (AI-based digital technologies) offers promising solutions for accurate breed identification, pedigree tracking and decision-making support. The integration of artificial insemination with artificial intelligence can serve as a strategic tool to prevent germplasm dilution while promoting breed-wise genetic improvement.

Why pure indigenous breeds are important for farmers

Cattle play a multifaceted role in rural livelihoods by contributing significantly to milk production and serving as draught animals for agricultural operations and transportation. In smallholder farming systems, bullocks continue to perform the majority of farm-related activities. Indigenous cattle, primarily classified as Zebu, are particularly suited for draught purposes due to the presence of a hump, which enhances their strength and endurance.

Indigenous cattle are widely recognized for their superior heat tolerance and ability to survive under harsh and extreme climatic conditions. Studies assessing the impact of climate change and rising environmental temperatures on dairy animals have indicated that global warming is likely to adversely affect milk production and reproductive performance. Among dairy species, crossbred cattle exhibit the greatest decline in milk yield and reproductive efficiency, followed by buffaloes, whereas indigenous cattle are the least affected due to their hardiness and adaptability.

Owing to their exceptional traits such as heat tolerance, resistance to ticks, pests, and diseases, and their capacity to thrive under adverse climatic conditions, indigenous cattle have been exported to several countries, including the USA, Brazil, and Australia, for the development of heat-tolerant and disease-resistant livestock populations. Furthermore, most indigenous cattle breeds possess the A2 allele of beta-casein, while exotic cattle predominantly exhibit a higher frequency of the A1 allele. Studies suggest that consumption of A1 milk may be associated with certain metabolic disorders such as diabetes and cardiovascular diseases, whereas A2 milk produced by indigenous breeds is not linked to such health concerns

Concept of Germplasm Dilution

Germplasm dilution refers to the gradual erosion of genetic purity, distinct phenotypic traits, and adaptive potential of a breed due to uncontrolled or unplanned breeding practices. In indigenous dairy animals, germplasm dilution often manifests as loss of breed-specific characteristics, reduced adaptability, and genetic homogenization.



Indigenous-to-Indigenous Breed Dilution: A hidden problem

Contrary to the common perception that germplasm dilution primarily results from exotic crossbreeding, intermixing of indigenous breeds poses an equally serious threat. Breeding of animals belonging to different indigenous breeds without a defined breeding objective leads to:

- Loss of breed identity
- Breakdown of locally adapted gene complexes
- Emergence of non-descript animals
- Difficulty in breed conservation and improvement programs

Such dilution is often irreversible and undermines long-term conservation efforts

How Germplasm Dilution Happens at Village Level

Germplasm dilution does not happen suddenly. It happens slowly due to small mistakes made repeatedly. Common reasons include:

- AI technician using available semen, not correct breed semen
- Farmer not knowing the exact breed of his animal
- No written record of past inseminations
- Belief that “any indigenous semen is good”
- Focus only on short-term milk increase

These small actions together create a big problem over time.

The Role of Farmers in Preventing Germplasm Dilution

Farmers play the most important role in protecting indigenous breeds.

Every farmer should:

- Ask the AI worker which breed semen is being used
- Refuse insemination if breed does not match
- Maintain a simple breeding record notebook
- Prefer semen from authorized centres
- Avoid repeated breed changes across generations



How new digital technology (Artificial Intelligence) can help farmers

- ✓ **AI-based Breed Identification:** Computer vision algorithms trained on large datasets of indigenous breeds can accurately identify animals based on facial features, horn shape and orientation, coat colour and patterns, body conformation etc. Mobile-based applications can assist AI technicians in real-time breed verification prior to insemination. Studies have been conducted on similar looking indigenous breeds such as like Sahiwal and Red Sindhi, Tharparkar and Haryana, Pantaneria cattle in which convolutional neural network model was able to identify cattle breeds with accuracy of 85-95%
- ✓ **Biometric Animal Identification Systems:** AI-enabled biometric tools such as facial and muzzle pattern recognition create a unique digital identity for each animal. These systems ensure accurate linkage of animals to their breed and breeding history, preventing repeated breed mismatches. Studies have been conducted for individual identification of animals using convolutional neural network achieving accuracy of approx. 95%
- ✓ **AI-driven Decision Support Systems:** Decision-support platforms integrated with AI can recommend appropriate semen based on animal profile, automatically block insemination in case of breed mismatch, generate alerts for potential dilution risks
- ✓ **DNA-based Breed Purity Assessment:** Genomic tools using single nucleotide polymorphism (SNP) markers can be used to enable precise determination of breed composition. AI algorithms can analyze genomic data to identify admixture levels, classify animals as purebred or crossbred, select genetically pure females for breeding programs
- ✓ **AI-assisted Bull Selection:** AI-based genomic evaluation aids can help in selecting breeding bulls that maintain breed purity, improve economically important traits, minimize inbreeding and genetic contamination
- ✓ **Digital Pedigree Recording and Traceability:** Digital livestock information systems are critical for long-term germplasm protection. AI-powered databases may enable recording of every AI event, traceability of semen use, monitoring of breed-wise population trends, identification of high-risk dilution zones
- ✓ **Farmer Awareness and Participatory Conservation:** Artificial intelligence can be leveraged to improve farmer awareness through mobile applications in local languages,



visual tools explaining breed differences, AI-based advisory services on breeding decisions. Informed farmers act as stakeholders in conservation rather than passive recipients of technology.

Challenges of Using Artificial Intelligence (AI) to Protect Indigenous Dairy Breeds: What Farmers Should Know

Artificial intelligence can help farmers protect indigenous dairy breeds by identifying the correct breed before artificial insemination and keeping digital breeding records, but its use also has several challenges at the village level. Many farmers have limited awareness and digital literacy, making it difficult to understand or trust mobile-based AI tools, especially when apps are in English or require smartphones and internet connectivity, which is often weak in rural areas. AI systems may also give incorrect results if animal photos are unclear or if indigenous breeds look very similar, and limited data on local breeds can reduce accuracy. The cost of devices, software, and DNA testing can be a burden for small farmers, and over-dependence on technicians or technology may lead to mistakes if systems fail or are misused. Therefore, while AI is a helpful support tool, it cannot replace farmer awareness, proper training, and careful human judgment in preventing germplasm dilution.

Conclusion

Indigenous dairy breeds are a valuable asset for farmers due to their adaptability, disease resistance, and suitability to low-input farming systems, but they are increasingly threatened by germplasm dilution caused by unplanned breeding and improper use of artificial insemination, including mixing of one indigenous breed with another. While artificial insemination remains an important tool for genetic improvement, its benefits can be realized only when it is used with correct breed identification, proper records, and responsible decision-making. New digital technologies based on artificial intelligence offer strong support by improving breed identification, record keeping, and monitoring of breeding practices; however, challenges such as limited awareness, digital literacy, connectivity issues, cost, and data limitations must be addressed. Ultimately, successful prevention of germplasm dilution depends on informed and alert farmers, well-trained technicians, supportive institutions, and the careful use of technology as an aid rather than a replacement for human judgment. By combining farmer awareness, correct artificial insemination practices, and appropriate use of artificial intelligence, indigenous dairy breeds can be protected, improved, and sustained for future generations.



Farmers Field School Approach

¹Deepanshu Bambu, ²Dr. Geeta Mohan

¹ Student, B.Sc. (Hons.), Faculty of Agriculture, Jagannath University, Jaipur (Raj.) 303901

²Professor, Faculty of Agriculture, Jagannath University, Jaipur (Raj.) 303901



ABSTRACT

The Farmers Field School (FFS) approach is a participatory and experiential learning method designed to improve farmers' knowledge, decision-making abilities, and agricultural productivity. Originating in Southeast Asia during Integrated Pest Management (IPM) programs, the approach has expanded globally to address crop production, livestock management, natural resource conservation, and climate-smart agriculture. FFS emphasizes "learning by doing," where groups of farmers regularly meet in the field to observe crop conditions, analyze problems, and adopt suitable farming practices. Unlike traditional top-down extension methods, FFS encourages active participation, collective learning, and local innovation. The approach empowers farmers by improving technical skills, leadership qualities, and social cooperation. It has contributed to reduced pesticide use, increased yields, improved household income, and enhanced environmental sustainability. Women and marginal farmers particularly benefit from the participatory nature of the program. Despite its advantages, challenges such as high operational costs, limited trained facilitators, and inadequate follow-up support may affect its effectiveness. Nevertheless, the Farmers Field School approach remains one of the most influential agricultural extension methods for sustainable rural development. This article discusses the principles, objectives, methodology, benefits, challenges, and future prospects of the Farmers Field School approach in agricultural extension systems.

Keywords: Farmers Field School, Agricultural Extension, Participatory Learning, Integrated Pest Management, Sustainable Agriculture, Rural Development.

Introduction:

Agriculture plays a vital role in ensuring food security, employment generation, and rural development in many countries. Farmers require continuous knowledge and skill development



to cope with changing climatic conditions, pest outbreaks, soil degradation, and market competition. Traditional extension systems mainly relied on one-way communication where experts transferred recommendations directly to farmers. However, these methods often failed to address local problems and farmers' practical needs.

The Farmers Field School (FFS) approach emerged as an innovative extension methodology that places farmers at the center of the learning process. It was first introduced by the Food and Agriculture Organization (FAO) in the late 1980s in Indonesia to help rice farmers manage pests effectively while reducing excessive pesticide use. Over time, the approach spread to many developing countries and expanded into different agricultural sectors.

The FFS approach is based on participatory education where farmers learn through observation, experimentation, and group discussion. Farmers meet regularly throughout the cropping season under the guidance of a trained facilitator. During these meetings, participants analyze field conditions, conduct experiments, and identify solutions to agricultural problems. This process strengthens farmers' confidence and encourages informed decision-making.

The approach has become increasingly important in promoting sustainable agriculture, climate resilience, and community empowerment. It helps farmers improve productivity while conserving natural resources and reducing environmental risks.



Figure 1 Farmers Field School

**Concept of Farmers Field School:**

A Farmers Field School is a group-based learning process where farmers gather in their own fields to study crop growth, pest management, soil health, and farm management practices. The field acts as the primary classroom, and learning occurs through direct observation and practical activities.

The core philosophy of FFS includes:

- Learning by doing
- Farmer participation and empowerment
- Group interaction and collective decision-making
- Problem-solving through experimentation
- Development of local leadership and innovation

Unlike conventional training programs, FFS does not simply provide recommendations. Instead, it enables farmers to understand ecological relationships and make independent decisions based on field observations.

Objectives of Farmers Field School Approach:

The major objectives of the Farmers Field School approach are:

1. To enhance farmers' technical knowledge and practical skills.
2. To promote sustainable and environmentally friendly farming practices.
3. To strengthen farmers' decision-making and problem-solving abilities.
4. To encourage collective action and community participation.
5. To reduce dependence on chemical inputs.
6. To improve farm productivity and income.
7. To build leadership and communication skills among farmers.

Principles of Farmers Field School:

The FFS approach operates on several important principles:



1. Participatory Learning

Farmers actively participate in all learning activities instead of passively receiving information.

2. Field-Based Education

The farm field serves as the main classroom where practical learning occurs.

3. Experiential Learning

Farmers gain knowledge through experiments, demonstrations, and direct observation.

4. Group Dynamics

Group discussions and teamwork improve social interaction and knowledge sharing.

5. Facilitator Role

The facilitator guides discussions and learning activities rather than acting as a lecturer.

Methodology of Farmers Field School:

The implementation of FFS generally follows a systematic process:

Selection of Farmers

Interested farmers from the village are selected to participate voluntarily. Groups usually consist of 20–30 members.

Identification of Problems

Farmers identify major agricultural problems such as pest infestation, low yields, or poor soil fertility.

Establishment of Learning Plots

Field plots are prepared for demonstrations and comparative experiments.

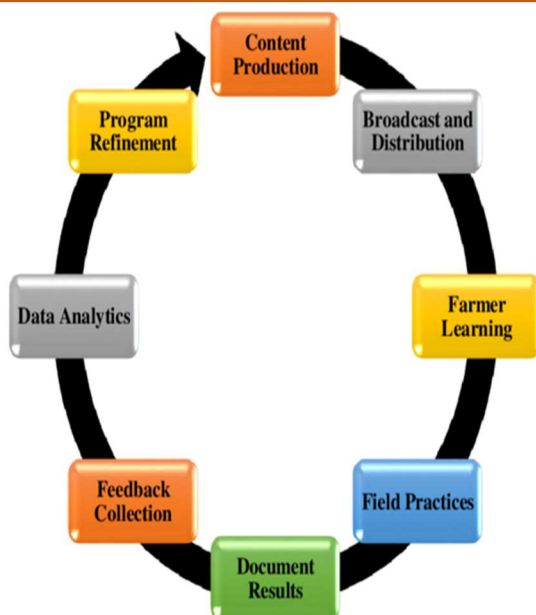


Figure 3 Tools for Knowledge Dissemination

Regular Meetings

Farmers meet weekly or biweekly during the cropping season to observe crop growth and discuss findings.

Agro-Ecosystem Analysis (AESA)

Participants analyze the interactions between crops, pests, soil, weather, and beneficial organisms.

Experimentation

Farmers conduct trials to compare different farming practices and technologies.

Evaluation and Graduation

At the end of the season, farmers evaluate the outcomes and share their experiences with the community.

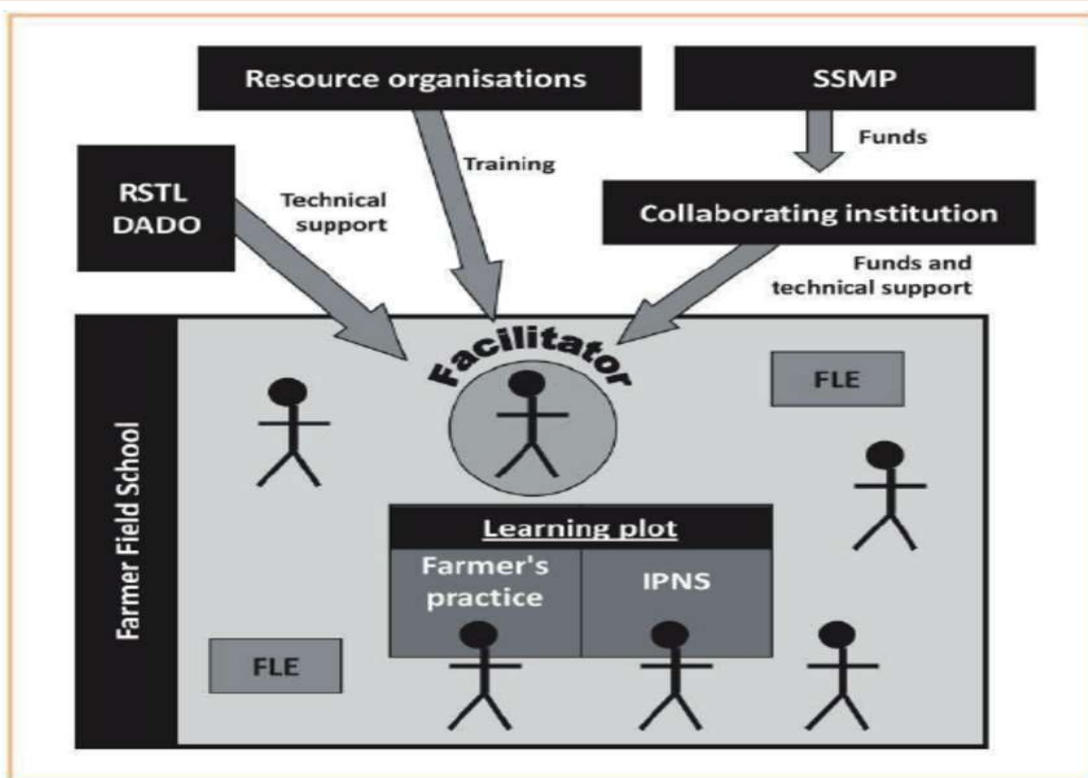


Figure 2. Role of Facilitators in FFS

Role of Facilitators in FFS:

Facilitators play a crucial role in the success of the Farmers Field School approach. They may be agricultural extension officers, scientists, NGO workers, or trained lead farmers.

Their responsibilities include:

- Guiding group discussions
- Encouraging participation of all members
- Assisting in field experiments
- Promoting critical thinking among farmers
- Providing technical support when required

Effective facilitators help farmers develop confidence and independent decision-making abilities.

Benefits of Farmers Field School Approach:



1. Improved Knowledge and Skills

Farmers develop practical knowledge about crop management, pest control, and soil health.

2. Reduction in Pesticide Use

FFS encourages Integrated Pest Management (IPM), reducing unnecessary chemical application.

3. Increased Productivity

Improved farming practices often lead to higher crop yields and better product quality.

4. Environmental Protection

Reduced chemical use contributes to biodiversity conservation and soil health improvement.

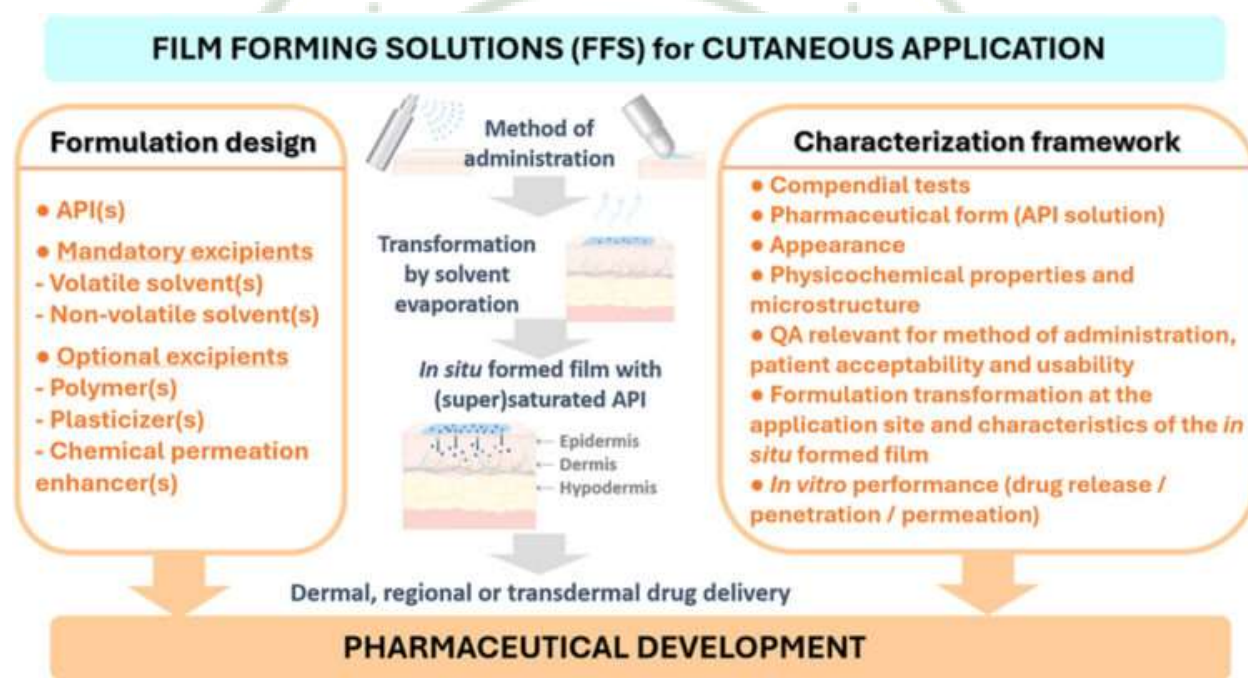


Figure 3 FFS in Different Areas

Application of FFS in Different Areas:

The Farmers Field School approach has been successfully applied in various agricultural and rural development activities:

Area	Application
Crop Production	Pest management, nutrient management



Area	Application
Horticulture	Vegetable and fruit cultivation
Livestock	Animal health and feeding management
Fisheries	Pond management and disease control
Climate-Smart Agriculture	Water conservation and adaptation practices
Organic Farming	Compost preparation and bio-input use

5. Empowerment of Farmers

Farmers gain confidence in analyzing problems and selecting suitable technologies.

6. Strengthening of Social Networks

Group learning promotes cooperation, communication, and collective action.

7. Better Income Opportunities

Improved production and reduced costs help increase household income.

Challenges of Farmers Field School Approach:

Despite its advantages, the FFS approach faces several limitations:

1. High Operational Cost

Conducting field sessions and demonstrations requires financial support.

2. Need for Skilled Facilitators

Success depends greatly on trained and experienced facilitators.

3. Time-Consuming Nature

Regular meetings throughout the season may discourage some farmers.

4. Limited Coverage

Only a small number of farmers can participate at one time.



5. Sustainability Issues

Programs may decline after external funding or institutional support ends.

Future Prospects of Farmers Field School:

The future of the Farmers Field School approach appears promising due to increasing demand for sustainable and climate-resilient agriculture. Integration of Information and Communication Technology (ICT), mobile advisory services, and digital learning tools can further strengthen FFS programs. Governments, universities, and development organizations are increasingly promoting participatory extension approaches to empower rural communities.

The inclusion of women, youth, and marginalized farmers in FFS programs can improve social equity and rural livelihoods. Climate-smart farming, organic agriculture, and natural resource management are expected to become major focus areas for future FFS initiatives.



Figure 4 Farmer Field School (FFS): A place where Fields Become Classroom and Farmers become Scientist.

Conclusion:

The Farmers Field School approach has transformed agricultural extension by promoting participatory and experiential learning among farmers. It empowers rural communities through knowledge sharing, practical skill development, and collective decision-making. By encouraging sustainable farming practices, reducing pesticide dependence, and improving



productivity, FFS contributes significantly to rural development and environmental conservation. Although challenges such as high costs and limited trained facilitators remain, the approach continues to be an effective extension strategy worldwide. Strengthening institutional support, capacity building, and digital integration can further enhance the impact of Farmers Field Schools in achieving sustainable agricultural growth and improved farmer livelihoods.

References:

1. Braun, A., Thiele, G., & Fernandez, M. (2000). *Farmer Field Schools and Local Agricultural Research Committees: Complementary Platforms for Integrated Decision-Making in Sustainable Agriculture*. Agricultural Research and Extension Network.
2. Davis, K. (2006). Farmer Field Schools: A Boon or Bust for Extension in Africa? *Journal of International Agricultural and Extension Education*, 13(1), 91–97.
3. Food and Agriculture Organization (FAO). (2016). *Farmer Field School Guidance Document*. Rome: FAO.
4. Pontius, J., Dilts, R., & Bartlett, A. (2002). *From Farmer Field Schools to Community IPM*. FAO Community IPM Program.
5. van den Berg, H., & Jiggins, J. (2007). Investing in Farmers: The Impacts of Farmer Field Schools in Relation to Integrated Pest Management. *World Development*, 35(4), 663–686.
6. Waddington, H., Snilstveit, B., White, H., & Anderson, J. (2014). Farmer Field Schools for Improving Farming Practices and Farmer Outcomes. *Campbell Systematic Reviews*, 10(1), 1–335



Occupational Health Hazards Among Women Agricultural Workers: A Review of Risks and Challenges

Dr.K.Spandana Deepika, Dr.K.Dhanasree and Ms. J.Ranjitha

Department of Extension Education and Communication Management (EECM),
College of Community Science, ANGRAU, Lam, Guntur - 522034.



ABSTRACT

Women constitute a substantial proportion of the agricultural workforce worldwide, particularly in low and middle-income countries, where they play a crucial role in food production, processing and household food security. Despite their contributions, women agricultural workers are exposed to a wide range of occupational health hazards that remain under recognized and insufficiently addressed. This review examines the major physical, chemical, biological, ergonomic and psychosocial health risks faced by women in agricultural settings. Drawing on existing literature, the paper highlights gender-specific vulnerabilities, structural inequalities and social cultural factors that exacerbate health risks. The findings emphasize the need for gender-sensitive occupational health policies, improved access to health care and targeted interventions to protect and promote the health and well-being of women agricultural workers.

KEYWORDS: Women agricultural workers, occupational health hazards, pesticide exposure, ergonomic risks, musculo-skeletal disorders, reproductive health, psychosocial stress, gender inequality, agricultural safety, rural women's health.

INTRODUCTION:

Agriculture is one of the most hazardous occupations globally, employing a large segment of the workforce, especially women. According to global estimates, women account for approximately 40-50% of agricultural labour involved in activities across different regions. They are engaged in developing regions sowing, weeding, harvesting, livestock, management and post-harvest processing. Despite their extensive participation, women agricultural workers



often operate in informal, unregulated a environment with limited occupational safety measures.

Occupational health hazards in agriculture include exposure to pesticides, heavy manual labour extreme weather conditions, zoonotic diseases and poor ergonomic practices. Women face unique Challenges due to biological factors, reproductive health concerns, unequal access to resources and gender-based discrimination. International Organizations such as the World Health Organization and the International Labour Organization have emphasized the need to address occupational health disparities, yet women in agriculture remain an undeserved population. This review aims to synthesize existing evidence on Occupational health hazards among women agricultural workers and discuss the associated risks and Challenges.

METHODOLOGY: This review adopts a narrative Literature review approach. Peer-reviewed articles, reports, and policy documents published between 2000 and 2024 were sourced from academic databases such as PubMed, Scopus and Google Scholar.

Publications from international organizations including the Food and Agriculture Organization were also reviewed. Studies focusing specifically on women or providing gender-disaggregated data were prioritised. Relevant findings were thematically analysed and categorized into major hazard domains.

FINDINGS AND DISCUSSION:

Physical and Ergonomic Hazards: Women agricultural workers frequently engage in repetitive tasks, prolonged stooping, lifting heavy loads and manual harvesting, leading to Musculo-skeletal disorders such as back pain, joint injuries and Chronic fatigue poorly designed tools and equipment, often tailored to male physiques, further increase ergonomic Strain.

Chemical Hazards: Exposure to pesticides and fertilizers is a major occupational risk. Women are often involved in Pesticide application, mixing and post-spraying activities without adequate personal protective equipment. Chronic exposure has been linked to respiratory disorders, skin diseases, neurological symptoms and adverse reproductive outcomes, including miscarriages and congenital anomalies.



Biological Hazards: Contact with livestock, soil and contaminated water exposes women to zoonotic infections, parasitic diseases, and vector-borne illnesses. Limited access to clean water and sanitation in agricultural fields exacerbates these risks.

Psychosocial Hazards: Women agricultural workers face long working hours, job insecurity, low wages, and dual workloads. Combining farm labour with domestic responsibilities. These Stressors contribute to mental health issues such as anxiety, depression and emotional exhaustion. Gender-based violence and harassment in agricultural settings further compound psychosocial risks.

Gender-specific challenges: Structural inequalities - such as limited land ownership, restricted access to training, healthcare's and social protection-intensify occupational health risks for women cultural norms often prevent women from voicing health concerns or seeking timely medical care, leading to underreporting and delayed treatment of work-related illnesses.

Conclusion:

Women agricultural workers experience a complex array of occupational health hazards shaped by the nature of agricultural work and entrenched gender inequalities. Physical strain, chemical exposure, biological risks and psychosocial stressors collectively threaten their health and productivity. Addressing these challenges requires gender-responsive occupational health policies, improved surveillance of women's work-related health issues, access to appropriate protective equipment and community-based health education. Strengthening legal protections and integrating women's voices into agricultural and labour Policymaking are essential for achieving safer and more equitable agricultural work environment's.

References:

1. Food and Agriculture Organization (2011). The state of Food and Agriculture: Women in Agriculture -closing the Gender Gap for development FAO.
2. International Labour Organization (2015) Safety and Health in Agriculture. ILO.
3. London, L, Beseler, C., and Bouchard, M.F. (2012). Pesticide exposure and health effects in women agricultural workers. Journal of Agro medicine, 17 (4):373-385.
4. Naidoo, S., Kromhout, H., and London, L. (2010) Musculoskeletal disorders in women farm workers. American Journal of Industrial medicine, 53 (8):835-846.
5. Rother, H.A. (2018). Gendered pesticide exposure and health outcomes. Environmental Research, 164:434-442.
6. World Health Organization (2021) Occupational Health Hazards of workers, WHO.



Artificial Intelligence and Drones: Measure, Monitor and Manage Soil Health

Kalyani Patil¹, Sunanda Biswas^{1*} and Bharat H. Gawade²

¹Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi-110012

² Division of Plant Quarantine, ICAR-NBPGR, New Delhi-110012.



ABSTRACT

Soil health assessment forms the foundation of sustainable agriculture, climate-resilient cropping systems, and informed land management. Conventional soil testing, although analytically precise, is limited by sparse sampling, high labour intensity, and slow turnaround times. Recent advancements in unmanned aerial vehicles (UAVs), miniaturized spectral sensors, and artificial intelligence (AI) have drastically expanded the possibilities for rapid, spatially explicit soil monitoring. UAV-based multispectral, hyperspectral, thermal infrared (TIR), and LiDAR sensing provide high-resolution data that can capture subtle spatial differences in soil organic carbon (SOC), moisture distribution, salinity, texture, and surface degradation. Concurrently, machine learning (ML) and deep learning (DL) algorithms transform high-dimensional spectral–thermal–structural inputs into accurate estimates of soil properties. This article synthesizes insights from Banerjee et al. (2025) together with globally verified peer-reviewed literature to provide a comprehensive evaluation of UAV–AI systems for soil health diagnostics. A detailed analysis of sensing principles, soil–spectral relationships, AI modelling strategies, and field-level applications is presented. The article concludes with a concise yet critical appraisal of major challenges and future research trajectories that will shape the integration of UAV-based soil intelligence into precision and climate-smart agriculture.

1. Introduction

Soil health, broadly defined as the continued capacity of soil to function as a vital living ecosystem supporting plants, animals, and humans, is increasingly recognized as a central component of food security and environmental sustainability (Doran & Zeiss, 2000). Soil systems regulate water infiltration and storage, nutrient cycling, carbon sequestration, and



biological activity. Yet, global soils are under severe pressure: widespread erosion, nutrient depletion, salinization, compaction, and loss of organic matter threaten agricultural productivity in many regions. These issues are exacerbated by climate change, which alters hydrological patterns, accelerates degradation, and increases the frequency of extreme events.

Effective soil health monitoring is essential but remains hampered by the limitations of traditional methods. Conventional soil analysis relies on discrete sampling followed by laboratory-based characterization of physical, chemical, and biological properties. While these measurements are accurate, they represent only a tiny fraction of the field. Soils exhibit strong small-scale heterogeneity; moisture, SOC, and nutrient concentrations vary over distances of meters or even cm. Moreover, soil properties change dynamically during the season due to rainfall, irrigation, crop growth, fertilizer application, and microbial processes. Thus, periodic sampling fails to capture temporal variability and cannot support real-time management decisions.

In this context, UAV-based remote sensing provides a transformative solution. Low-altitude flight enables cm-level imaging with unprecedented flexibility in timing, frequency, and cost-effectiveness. UAVs can be equipped with multispectral, hyperspectral, thermal infrared, LiDAR, and RGB photogrammetric sensors capable of detecting physical, optical, thermal, and structural signatures linked to soil properties. Studies such as Banerjee et al. (2025) demonstrate how UAV thermal and multispectral sensing can reveal soil moisture heterogeneity and crop–soil interactions in semi-arid Vertisols.

Complementing UAV sensing, artificial intelligence models—including Random Forest (RF), Support Vector Machines (SVM), gradient boosting algorithms, and deep neural networks—are capable of learning nonlinear relationships between spectral features and laboratory-measured soil attributes. Hyperspectral datasets containing hundreds of narrow spectral bands can be analyzed effectively using CNNs and transformer architectures, which extract spectral–spatial features beyond the capability of empirical indices. Together, UAVs and AI form an integrated soil intelligence framework that is revolutionizing soil diagnostics, enabling rapid, non-destructive monitoring at scales ranging from small plots to large agricultural landscapes.



2. Drone-Based Sensing Technologies for Soil Health Assessment

2.1 Multispectral UAV Sensing

Multispectral sensors capture reflectance in a limited set of broad spectral bands—typically blue, green, red, red-edge, and near-infrared (NIR). These sensors are widely used due to their low weight, affordability, and compatibility with standard UAV platforms. Soil reflectance in the visible–NIR domain is sensitive to organic matter, iron oxides, moisture, mineralogy, and residue cover. Red-edge wavelengths, although originally used for vegetation monitoring, have shown strong relationships with soil mineral composition and moisture content. For example, an increase in soil organic matter typically reduces reflectance in the red and NIR regions due to darker soil colour and greater absorption (Adewopo et al., 2014). Multispectral UAVs have been successfully used to map SOC variability, detect saline patches, quantify residue cover, and assess surface crusting in dryland systems.

2.2 Hyperspectral UAV Sensing

Hyperspectral sensors represent one of the most powerful tools for soil analysis. By capturing hundreds of contiguous spectral bands from 400 to 2500 nm, these sensors provide rich spectral signatures related directly to mineralogy, clay content, soil organic matter, and moisture. Key diagnostic absorption features—such as the water absorption bands at 1400 and 1900 nm, and clay mineral absorptions at ~2200 nm—allow detailed discrimination of soil constituents (Ben-Dor et al., 2009). UAV-borne hyperspectral sensors have become increasingly compact and are now capable of delivering field-scale mapping of SOC, clay minerals, and nutrient proxies with accuracy comparable to laboratory spectroscopy (Weidong et al., 2016). Hyperspectral imagery is particularly suited for semi-arid regions, where mineralogical variability is high and vegetation cover is sparse, making soil signals more pronounced.

2.3 Thermal Infrared (TIR) Sensing

Thermal infrared UAV sensors detect emitted radiation from the soil surface, enabling estimation of surface temperature and thermal inertia. Soil temperature is a strong proxy for soil moisture because wet soils cool through evaporation, whereas dry soils heat rapidly. This principle has enabled UAV-TIR systems to map moisture gradients, detect hydrologic anomalies, identify compacted zones, and monitor evaporative fluxes (Sobrino et al., 2016). TIR sensing is especially insightful in cropping systems where soil moisture is spatially heterogeneous due to irrigation patterns, soil structure, or variable infiltration. Integration of



TIR with multispectral and hyperspectral datasets improves predictive models for both moisture and nutrient stress.

2.4 LiDAR and High-Resolution Surface Modelling

UAV-LiDAR systems produce dense 3D point clouds capable of capturing micro-topographic variations at cm resolution. These fine-scale structural datasets are invaluable for identifying rills, gullies, erosion scars, compaction ridges, and small-scale surface irregularities that influence hydrology and nutrient distribution. LiDAR-based terrain models have been used to quantify erosion processes and sediment transport pathways with high precision (Wallace et al., 2016). Structure-from-Motion (SfM) photogrammetry using RGB imagery serves as a cost-effective alternative, generating DEMs suitable for many applications, including mapping crust formation, tillage patterns, and small-scale depressions.

2.5 Sensor Fusion for Comprehensive Soil Assessment

No single sensor captures all soil attributes; therefore, multi-sensor fusion is increasingly recognized as essential. Fusing hyperspectral with TIR data enhances moisture–SOC interactions, while combining LiDAR with multispectral data improves understanding of erosion–vegetation–soil dynamics. Integrated sensing systems provide a holistic view of soil health, enabling simultaneous assessment of chemical properties (SOC, nutrients), physical indicators (structure, compaction), and hydrological behaviour (moisture, infiltration).

TABLE 1. Summary of UAV Sensors Used for Soil Health Monitoring and Their Soil-Relevant Capabilities

Sensor Type	Spectral Range / Principle	Key Soil Properties Detected	Strengths	Limitations	References
Multispectral	450–900 nm (VIS–NIR)	SOC, moisture, residue cover, salinity, colour-	Affordable, lightweight, easy to process	Limited spectral detail; poor clay discrimination	Mutanga et al., 2012; Adewopo et al., 2014



		based mineralogy			
Hyperspectral	400–2500 nm (VIS–NIR–SWIR), 5–10 nm bands	SOC, clay minerals, texture, salinity, water absorption features	High chemical/mineral sensitivity; strongest soil diagnostics	Expensive; large data size; sensitive to illumination	Ben-Dor et al., 2009; Weidong et al., 2016
Thermal Infrared (TIR)	8–14 μm	Soil moisture, compaction, crusting, evaporative flux	Extremely sensitive to moisture; good for irrigation insights	Influenced by atmospheric conditions	Sobrinho et al., 2016
LiDAR	Active laser ranging	Micro-topography, compaction, erosion, gully volume	Best for structural soil indicators; works under low light	Expensive; high processing requirement	Wallace et al., 2016
RGB + SfM Photogrammetry	400–700 nm, Structure-from-Motion	Surface roughness, residue cover, crusting, erosion	Very cheap; DEMs with cm resolution	No chemical soil info; light-dependent	—



3. Artificial Intelligence and Machine Learning for Soil Property Prediction

3.1 Machine Learning Frameworks

AI has become indispensable for extracting meaningful soil information from complex UAV datasets. Random Forest (RF) remains one of the most reliable algorithms for predicting SOC, clay content, and moisture due to its ability to model nonlinear interactions and its robustness to noise (Vašát et al., 2017). Support Vector Machines (SVM) are effective for classifying salinity levels and soil types using multispectral imagery, as demonstrated in several coastal and irrigated agroecosystems (Zhang et al., 2020). Gradient-boosting algorithms such as XGBoost and LightGBM have shown high predictive accuracy for soil nutrients, particularly nitrogen, when trained with multispectral–thermal fusion datasets (Wang et al., 2022).

3.2 Deep Learning Approaches

Deep learning, particularly convolutional neural networks (CNNs), has revolutionized spectral analysis. CNNs learn hierarchical spatial–spectral features automatically, enabling superior prediction of SOC, clay minerals, and salinity from hyperspectral UAV imagery (Yuan et al., 2021). Recent research shows that transformer architectures, originally developed for natural language processing, outperform classical CNNs in modelling long-range spectral dependencies in hyperspectral data. Hybrid CNN–LSTM models have also been applied to capture spatiotemporal soil dynamics, such as seasonal moisture variation and nutrient mobilization. These approaches enable the development of predictive soil intelligence systems that continuously update with new UAV flights.

TABLE 2. Common Soil Diagnostic Spectral Features and Their Interpretations

Wavelength / Region	Soil Property	Spectral Behavior	Interpretation / Diagnostic Use	Reference
~450 nm	Salinity / carbonates	Higher reflectance	Salt crusts are bright in blue region	Clark et al., 2005
670 nm (Red)	SOC, Fe-oxide	Lower reflectance with higher SOC	Dark organic soils absorb more red light	Adewopo et al., 2014



700–740 nm (Red-edge)	Clay minerals, Fe-oxides	Slope shift	Sensitive to mineralogy and moisture	Mutanga et al., 2012
1400 & 1900 nm	Soil moisture	Deep absorption features	Direct diagnostic for water content	Ben-Dor et al., 2009
2200 nm	Al–OH, Mg–OH	Sharp absorption	Identifies kaolinite, smectite, illite	Weidong et al., 2016
2300–2350 nm	Carbonates	Absorption shoulder	Indicates calcite/dolomite content	Clark et al., 2005

4. Applications of UAV–AI Systems in Soil Health Monitoring

4.1 Soil Moisture Mapping

UAV-based soil moisture mapping integrates TIR and multispectral imagery to produce high-resolution moisture distribution maps. Moisture is a major driver of microbial activity, nutrient availability, and crop performance, making it essential for precision irrigation. AI models can estimate moisture content with high accuracy, supporting site-specific irrigation scheduling in water-limited environments.

4.2 Soil Organic Carbon and Nutrient Assessment

SOC influences soil fertility, structure, and climate mitigation potential. Hyperspectral SWIR bands are strongly correlated with SOC due to absorption by organic functional groups. AI models trained on hyperspectral UAV data can quantify SOC with laboratory-level precision (Weidong et al., 2016). Nutrients such as nitrogen can be indirectly assessed using thermal, multispectral, and structural indicators integrated through ML models.

4.3 Soil Texture, Mineralogy, and Structure

Texture determines water retention, infiltration, nutrient holding capacity, and susceptibility to degradation. UAV hyperspectral and LiDAR integration enables mapping of clay-rich and sandy soils, identification of smectite-dominant zones, and detection of compaction patterns. These datasets support land preparation, tillage planning, and soil conservation strategies.



4.4 Soil Salinity and Sodicity Monitoring

Salinity alters soil reflectance through increased brightness and characteristic spectral shifts. UAV multispectral–hyperspectral datasets combined with SVM classification effectively detect saline patches, enabling early management interventions to prevent yield loss (Zhang et al., 2020).

4.5 Soil Degradation, Erosion, and Crust Formation

High-resolution DEMs generated from LiDAR and SfM photogrammetry allow quantification of soil erosion features such as rills, gullies, and sediment deposition zones. Monitoring these features over time provides insights into erosion progression and the effectiveness of conservation structures. UAV structural data also reveal surface crust formation and compaction that restrict root growth and reduce infiltration.

5. Challenges and Future Prospects (Concise)

Despite substantial progress, UAV-based soil monitoring faces limitations including high sensor costs (particularly hyperspectral and LiDAR), regulatory restrictions on flight operations, insufficiently large training datasets for deep learning, and challenges in generalizing AI models across diverse soil types. Future research must focus on developing universal soil spectral libraries, improving sensor miniaturization, advancing multi-sensor fusion algorithms, integrating edge-based AI for real-time soil analytics, and establishing standardized workflows for scalable soil health monitoring.

6. Conclusions

UAV–AI systems represent a paradigm shift in soil health monitoring. The fusion of high-resolution spectral, thermal, and structural data with advanced AI models enables rapid, non-contact, and spatially comprehensive assessment of soil physical, chemical, and hydrological properties. By overcoming the limitations of conventional soil testing, UAV-based soil intelligence supports precision agriculture, climate-smart farming, erosion management, and carbon accounting. Continued innovation in sensor technology, deep learning, multi-sensor integration, and field validation will expand the utility of UAV-based soil diagnostics, making them essential tools in future agricultural and environmental monitoring frameworks.



References

- Adewopo, J. B., et al. (2014). Multiscale soil spectral characterization. *Soil Science Society of America Journal*, 78(6), 1868–1880.*
- Ben-Dor, E., Taylor, R., Hill, J., Demattê, J. A., & Whiting, M. L. (2009). Hyperspectral soil mapping. *Geoderma*, 152(1–2), 126–142.*
- Clark, R. N. et al. (2005). *USGS Spectral Library*.
- Doran, J. W., & Zeiss, M. R. (2000). Soil health and sustainability. *Applied Soil Ecology*, 15(1), 3–11.*
- Mutanga, O., Adam, E., & Cho, M. A. (2012). High-density multispectral mapping. *Remote Sensing of Environment*, 124, 48–56.
- Sobrino, J. A., et al. (2016). Thermal infrared temperature retrieval. *Remote Sensing of Environment*, 182, 244–255.
- Vašát, R., et al. (2017). SOC prediction using Random Forest. *Geoderma*, 285, 105–118.
- Wallace, L., et al. (2016). UAV–LiDAR terrain mapping. *Remote Sensing*, 8(6), 469.
- Wang, H., et al. (2022). Nutrient prediction using XGBoost. *Computers and Electronics in Agriculture*, 198, 107015.
- Weidong, L., et al. (2016). Hyperspectral SOC estimation. *PLoS ONE*, 11(3), e0151355.
- Yuan, L., et al. (2021). CNN modeling of hyperspectral soil reflectance. *ISPRS Journal of Photogrammetry and Remote Sensing*, 172, 74–88.
- Zhang, T., et al. (2020). UAV salinity mapping with SVM. *Geoderma*, 365, 114181.



Lumpy Skin Disease as an Emerging Threat for Bovines in India

Manoranjan Rout^{1*}, Suvankar Sethi² and Jajati Keshari Mohapatra³

¹Senior Scientist, ²Additional District Veterinary Officer, ³Principal Scientist
^{1,3}ICAR-National Institute on Foot and Mouth Disease, International Centre for Foot and Mouth Disease, Bhubaneswar, Odisha, 752050, India

²Animal Welfare, Paralakhemundi, Fisheries and Animal Resources Development Department, Government of Odisha, India



ABSTRACT

Lumpy skin disease (LSD) in India severely constrains livelihoods of farming community. This emerging threat for the country is caused by LSD virus (LSDV) within genus *Capripoxvirus* of family *Poxviridae* is an Office International des Epizooties (OIE) notifiable livestock disease. After its first report in 1929 in Zambia, it was spread throughout Africa, Asia and Europe. Large ruminants including cattle and water buffalo in Southeast Asia are the primary victims of the virus. Clinical signs in affected animals may vary from subclinical to high morbidity/mortality. Characteristic appearance of lump like nodules in the skin and mucous membrane gives its name 'LSD'. The virus has not yet been shown to have zoonotic potential. Prophylactic vaccination is the only practical method to prevent LSD along with other zoosanitary measures.

Keywords: LSD, Poxvirus, Skin, Vaccine

Introduction

Lumpy skin disease (LSD) achieved its first identity in 1929 in Northern Rhodesia (presently Zambia) with the name 'pseudo urticaria'. The disease has several other synonyms like Neethling virus disease, exanthema nodularis bovis, knopvelsiekte etc. India recorded its first outbreak in Odisha in August 2019 that was reported to the Office International des Epizooties (OIE/WOAH) on 18th November 2019 subsequently targeting many states of the country. In 2020, LSD was reported in Nepal, Sri Lanka, Bhutan, Bangladesh, Vietnam, and Southeast China.



LSD impacting the economy

LSD impacts the economy during outbreak where it reduces the milk yield during pyrexia caused by the viral infection and mastitis caused by secondary bacterial infection. LSD is a disease with high morbidity (2-45%) and low mortality (10%). The losses are direct and indirect, where direct losses include low milk yield and poor growth, abortion, mortality during complication etc. On the other hand, indirect losses include decreased productivity of the affected animals, cost on treatment and additional burden on management.

First ever LSD outbreaks in India

India reported the first LSD outbreak on 12th August 2019 in the Mayurbhanj district of Odisha, second at Patalipura on 20th August 2019 and the third in Bhadrak of Odisha. The first report from the country was submitted to the OIE/WOAH on 18th November 2019. Odisha is a cyclone-prone state that was targeted by 'fani' during May 2019 causing serious loss of livelihood and livestock of coastal farmers. After this, animals in the coastal districts exhibited nodular lesions like LSD that might have been due to movements of livestock outside of national borders or movements of vectors from neighboring countries. By and large, Illegal shift of sick animals or their products, fomites through the porous Indo-Bangladesh border, or wind-driven blood-sucking vectors are speculated as the origin and source of LSD in India.

Etiology

LSD virus is a member of the genus *Capripoxvirus*, subfamily *Chordopoxvirinae* within the family *Poxviridae*. The genus *Capripoxvirus* (CaPV) comprises three viruses; sheeppox virus (SPPV), goatpox virus (GTPV) and LSDV. 'Neethling', the sole LSDV serotype was first identified in South Africa. The mature capripox virion has an average dimension of 320x260 nm with a complex shape enclosed in a lipid enveloped with a double stranded DNA (~151 kbps) looking like a brick. There does exists a 98% sequence similarity between 3 species of CaPVs, for which GTPV and SPPV vaccines can be used against LSD, where LSD vaccine is not licensed for practice.

Virus stability and sensitivity

LSDV shows stability for long periods in high temperatures and dryness surviving in contaminated animal sheds for different durations e.g., 33 days in necrotic skin nodules, 35 days in desiccated crusts, 3 months in dried scabs in skin, 3 weeks in air-dried hides and 18 days in air-dried hides at room temperature. The virus is susceptible to various chemicals e.g.,



0.5% ammonium, 2-3% sodium hypochlorite/bleach, 1:33 diluted iodine compounds, 1% formalin, chloroform, 20% ether, 2% phenol and 0.5% quaternary ammonium compounds. The virus is sensitive to very high or very low pH levels, while remains constant between pH 6.6 and 8.6 at 37 °C.

Susceptible hosts

Cattle acts as the primary natural host for LSDV. Water buffaloes and yaks may also be the host. Asiatic water buffaloes (*Bubalus bubalis*) are regarded to bear limited susceptibility to the virus. Indigenous bovines are relatively resistant than exotic and crossbred cattle. Young calves, cows in lactation and malnourished animals are better victimized. African buffalo (*Synercus caffer*) may act as reservoir host for the virus. Infected buffaloes hardly exhibit clinical signs, but antibody titre has been detected.

Zoonotic potential

The zoonotic potential of LSDV has not yet been reported by OIE. On contrary, sporadic and anthroponotic transmission of LSD virus to humans has been reported after the widespread outbreak in cattle in Cairo and Egypt during 2018-2019 (Kamal, 2019), where humans exhibited symptoms similar to skin nodules without resembling abscess on limbs in cattle. The report also suggested that LSD virus could infect humans by inhalation and by direct contact with fomites.

Epidemiology and transmission

Summer and autumn are the usual outbreak season of the vector-borne disease LSD that coincides with a favorable breeding time of vectors enhancing the mechanical and biological transmissions of the virus. It is transmitted by mosquitoes (*Aedes* spp., *Anopheles* spp., *Culex* spp.), ticks (*Rhipicephalus* spp. and *Amblyomma* spp.) and Diptera (*Haematopota* spp. and *Stomoxys* spp.). Things coming in contact with secretions from infected animals that are shared by other animals help transmission. The virus can be transmitted vertically from an infected dam to the calf. The virus can persist for 42 days after infection in semen and can be the source of transmission through mating or artificial insemination. Infected bulls with symptoms can ejaculate virus in semen for up to 22 days.



Clinical disease

Clinical signs after the incubation period can be classified into 4 phases:

Phase 1: This phase follows after the incubation period and is the febrile phase, where the animals develop fever as high as 103-106°F for about a week with lack of appetite, depression, nasal discharge, lacrimation, hypersalivation and reduction in milk.

Phase 2: This phase characterizes the development of nodular lesions in the skin and mucous membranes mostly on the head, neck, limbs, genitalia, perineum, udder, mucous membrane, nasal and oral cavities that are circumscribed, firm, round and raised with involvement of the skin and underlying subcutaneous tissue occasionally even the muscles (Figures 1, 2 and 3).

Phase 3: In this phase, nodular lesions get ulcerated and necrotic (sit-fast) with exudation of serum especially from limbs eventually becoming fibrotic that may persist for several months. The regional lymph nodes (subscapular and precrural region) become palpable after getting enlarged and lumpy lesions of the body may be felt. Peculiar ring-like lesions may develop on muzzle in the nares and oropharynx. Secondary infections may lead to myiasis and mastitis.

Phase 4: After about 30 days, ulcers get completely healed up with hyperpigmentation of the lesion and thickening of the skin.

Pathogenesis

LSD, an epitheliotropic ailment causes vasculitis and lymphadenitis after localized and systemic reactions. In natural scenario, the incubation period is 4 days to 4 weeks. Arthropod vectors inoculate LSDV into the skin and that enters the bloodstream with intradermal replication in fibroblasts, macrophage, pericytes and endothelial cells developing viremia. The affinity of the virus for keratinocytes causes epithelial hyperplasia and ballooning degeneration leading to edema and necrosis, while thrombosis and infarction may occur in some cases. The skin may become grey-pink in color with nodular texture with ulcerated caseous necrotic cores. Once recovered the animal becomes immune for about 6 months.

Gross pathology

The gross pathology of LSD is characteristic for the disease for grading its severity and impact. The necropsy findings may reveal vesicles, erosions, ulcers in the mucous membranes of the mouth, abomasum, trachea and lungs. Throughout the internal organs, lung congestion and nodules were observed during necropsies carried out in 33 cattle of Azerbaijan (Zeynalova et



al. 2016). LSD virus causes major vascular changes in skin lesions, including vasculitis that are reported only in CaPV family, not in other poxviruses.

Microscopic pathology

The LSD histopathology is characteristic and distinctive. Acute skin injuries include lymphangitis, vasculitis, thrombosis, infarction, edema and necrosis. The affected areas are infiltrated with eosinophils, lymphocytes and macrophages. Intracytoplasmic eosinophilic/eosinophilic-purple inclusions staining pink with eosin are found in keratinocytes, macrophages, endothelial cells and pericytes, also in sebaceous glands and hair follicles having a clear halo around them. The swollen epidermis and dermis infiltrated with large epithelioid macrophages called as “cellules claveleuses”, are typical of sheeppox infection. The necrotic tissue falls off leaving an ulcer that heals slowly (Moudgil et al., 2023). In early lesions, macrophages are accompanied by plasma cells and lymphocytes, while in older lesions, fibroblasts and polymorphonuclear leukocytes are found with some red blood cells. Signs of proliferation of the endothelial cells of blood vessels in the dermis and subcutis with lymphocytes infiltration around them leading to clotting and necrosis of the vessels and tissues.

Diagnosis

The presumptive diagnosis can rely on characteristic skin lesions and clinical signs. However, laboratory methods like molecular, serological tests and virus isolation are to be employed for confirmation. OIE recommends virus neutralization test as the gold standard test among serological tests. Virus isolation can be performed from infected materials blood, scab, skin nodules etc. Molecular techniques are polymerase chain reaction (PCR) or real-time-PCR (RT-PCR).

Early lesions (those without necrosis) on the skin before development of neutralizing antibodies within the first week of the onset of clinical symptoms can be taken for virus isolation and electron microscopic examination. During the viremia, blood in EDTA or heparin can be used to isolate the LSD virus from buffy coat. The most vulnerable cells for virus isolation are ovine dermis cells or lamb testis cells (Liang et al., 2022).

- a) **Electron microscopy:** Within a few hours of receipt of biopsy samples, a transmission electron microscopy (TEM) diagnosis is done in negatively stained preparations. Orthopox virions have a much rounder profile and smaller lateral bodies than mature capripox virions having dimension of 320x260 nm.



- b) **Fluorescent antibody tests:** FAT can detect Capripoxvirus antigen on the cover-slips or tissue culture slides infected with the virus.
- c) **ELISA:** It gives a useful diagnosis
- d) **Differential diagnosis:** LSD needs to differentially diagnosed from bovine papular stomatitis (Parapoxvirus), pseudolumpy skin disease (bovine alpha herpes virus), pseudocowpox (Parapoxvirus), Bovine bites, herpes mammillitis (bovine herpesvirus 2), Vaccinia virus and Cowpox virus (Orthopoxviruses), dermatophilosis, cutaneous tuberculosis, demodicosis, tick besnoitiosis, *Hypoderma bovis* infection, vesicular stomatitis, ringworm, photosensitization, urticaria, onchocercosis (Ratyotha et al., 2022).

Treatment

Like other viral disease, there is no specific treatment for LSD. However, supportive treatments may include antiparasitic, anti-inflammatory and antipyretic drugs, medicines to increase appetite and antibiotics to prevent secondary bacterial infection.

Prevention and control

Control and zoo sanitary prophylactic measures:

- i. **Strict control on animal movement:** LSD affected animals should be on strict control of movement
- ii. **Biosecurity actions:** Grazing restriction, right disposal of carcass, de-contamination of premises with disinfectant, quarantine
- iii. **Vector control:** Vector traps or insecticides can be used.
- iv. **Vaccination:** Types of LSD vaccines are (1) Attenuated LSDV vaccines (Neethling vaccines) are currently effective to prevent LSD in cattle; (2) Attenuated SPPV vaccines and attenuated Gorgan GTPV vaccine are suitable for the areas with SPPV and LSDV outbreak. Goatpox virus is more closely related to the LSDV than SPPV.
 - a) Live attenuated vaccine based on SIS Neethling type (LumpyVax®, MSD Animal Health Intervet, South Africa) with recommended dose of 1 ml S/C safe for cattle of all age groups



- b) Vaccines with cell-adapted Neethling strain are produced by Onderstepoort Biological Products; OBP, South Africa (Lumpy Skin Disease vaccine for cattle) and Bovivax LSD N® (freeze-dried), MCI SantéAnimale, Morocco. The dose of both vaccines is 2 ml by S/C route given to calves at 6 months of age and booster annually offering 3 years of protection
- c) Yugoslavian RM 65 sheeppox strain and Romanian sheeppox strain are utilized as vaccines against LSD.
- d) Lumpi-ProVacind is a homologous live-attenuated LSD vaccine offering 100% protection against fatal LSDV challenge.
- e) *Indian vaccines:*
 - i. Live-attenuated LSDV (Ranchi strain) vaccine
 - ii. Live attenuated sheeppox vaccine (strain SPPV Srin 38/00) by ICAR-IVRI
 - iii. Live attenuated Raksha Goatpox vaccine (Uttarkashi strain) by ICAR-IVRI.

Conclusion

The disease once exotic to India, is now an emerging threat victimizing the bovine population. The loopholes in different zoosanitary measures and improper control measures at the border areas along with lack of proper quarantine protocols are the probable points that need a vivid analysis so that other such diseases with economic significance can be prevented from incursion into the country. Once a disease gets introduced, then public awareness, proactive steps by the veterinary authorities and veterinarians along with development of preventive vaccines and ensuring the practice of proper vaccination become imperative. Vector control of course occupies a very crucial position in controlling the disease. Apart from vector control, focus on strict quarantine and movement control should never be underemphasized.

References

- Kamal, S.A., 2019. Comparative studies on lumpy skin disease virus in human. *Medical and Clinical Archives* 3, 1-8.
- Liang, Z., Yao, K., Wang, S., Yin, J., Ma, X., Yin, X., Wang, X., Sun, Y., 2022. Understanding the research advances on lumpy skin disease: A comprehensive literature review of



experimental evidence. *Frontiers in Microbiology* 13, 1065894. doi: 10.3389/fmicb.2022.1065894.

Moudgil, G., Chadha, J., Khullar, L., Chhibber, S., Harjai, K., 2023. Lumpy skin disease: A comprehensive review on virus biology, pathogenesis, and sudden global emergence. c2023.

Ratyotha, K., Prakobwong, S., Piratae, S., 2022. Lumpy skin disease: A newly emerging disease in Southeast Asia. *Veterinary World* 15(12), 2764-2771. doi: 10.14202/vetworld.2022.2764-2771.

Zeynalova, S., Asadov, K., Guliyev, F., Vatani, M., Aliyev, V., 2016. Epizootology and molecular diagnosis of lumpy skin disease among livestock in Azerbaijan. *Frontiers in Microbiology* 7, 1022. doi: 10.3389/fmicb.2016.01022.

Photos with captions

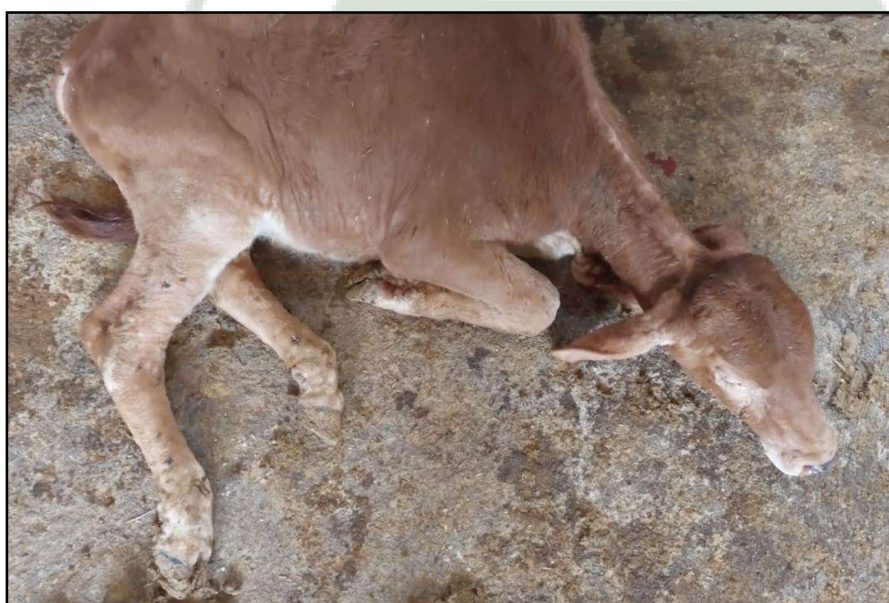


Figure 1: Lumpy nodules on skin of left and right leg of a desi bovine calf



Figure 2: Nodular lesions along with lumpy swellings on skin of right thoracic and abdominal region of cattle



Figure 3: Nodular lesions complicated with secondary infections on left side of cattle



The Edible Rooftop: A concept of new gardening

Dr. Swapnil Dnyaneshwar Deshmukh

Assistant Professor Section of Horticulture

P. R. Pote Patil College of Agriculture, Amravati



INTRODUCTION

The concept of a backyard garden is, in fact, quite old. Traditionally, a backyard garden involved cultivating vegetables, fruit trees and flowering plants in the open space surrounding one's home or backyard of house using kitchen waste water. It is used for growing plants for eating, flavouring food and often some medicinal plants. However, due to the ever-increasing urbanization of modern times, virtually no open space remains around residential properties. Wherever one looks, one sees a "jungle" of cement and concrete; adding to this scenario are the towering apartment complexes built under the "flat system" where construction leaves absolutely no open ground, and even the space beneath the building must be allocated for vehicle parking.

In such situations, a beautiful kitchen garden can be cultivated in pots on the home's terrace or in balcony. Such a garden not only enhances the aesthetic appeal of the house but also keeps the mind feeling cheerful and refreshed.

The objectives of a Terrace or Balcony Kitchen Garden:

- To make optimal use of the available space on the terrace and balcony.
- To enhance the overall beauty of the home.
- To fulfill the household's requirements for vegetables, flowers and fruits.
- To provide a supply of fresh, chemical-free produce.
- To mitigate temperature fluctuations.
- To create a clean and pleasant environment.



If you wish to cultivate a kitchen garden on a terrace or balcony, the first step is to ensure or make necessary arrangements that no water leaks through the floor. Furthermore, this space must be open to adequate sunlight and ventilation. When undertaking the planting process, one must take into account the combined weight of the soil, water and the potted plants themselves. To this end, it is essential to assess the load-bearing capacity of the terrace or balcony.

To cultivate such a backyard garden, one can utilize earthen or cement pots of various sizes, empty plastic containers, unused buckets, water tanks and similar items. These objects can be easily moved from one location to another. However, one should avoid using items of very dark colors, as dark colors absorb heat, which can potentially damage the plant roots during the summer season.

It is essential that every pot or container used has a drainage hole at the bottom. This allows excess water to drain away, preventing the plant roots from rotting. When selecting pots, it is necessary to take into account the growth, development and size of the plants. Furthermore, the placement of the pots can be determined based on the availability of sunlight.

Method for preparing pots for planting saplings –

When preparing pots for saplings, create a mixture consisting of one part soil, one part manure (or compost/leaf litter) and one part sand; then, fill the pots with this mixture. To eradicate harmful pests and fungi present in the soil, mix in 50 to 100 grams of neem cake or 10 to 15 grams of *Trichoderma*. If *Trichoderma* is added, allow the mixture to sit and mature for 10 to 15 days before filling the pots.

Doing this will protect the plants from various diseases and pests. When filling the pots, place a small piece of broken pottery or bricks at the bottom positioned so that it does not block the drainage hole to ensure proper drainage of excess water. While filling the pots, leave a space of 1–2 inches at the top to facilitate watering the plants.

Selection of Vegetable and Flower Crops –

Vegetable crops can be broadly categorized into two types: first, those that are cultivated by sowing seeds directly and second, those for which seedlings are first raised and subsequently transplanted.



Flowering plants are typically available for purchase at nurseries. One should procure plants suitable for the current season from a reputable nursery and proceed with their planting. In the case of marigolds, seedlings must first be raised before they are transplanted.

For vegetables such as brinjal, chili, tomato, onion, cabbage, etc., seedlings need to be prepared; to do this, the seeds are initially sown on a flat nursery bed for germination. Once the seedlings have grown to an age of 1 to 1.5 months, they should be transplanted.

Additionally, vegetables such as okra, spinach, fenugreek, radish, coriander, garlic, bitter gourd, etc., are cultivated by sowing seeds directly. Seeds should be sown in pots filled with soil, covered with a mixture of soil and cow dung manure and then watered. Germination typically begins within 5 to 6 days. To prevent the seedlings from drying out or wilting after sprouting, it is essential to treat the seeds with a fungicide such as Bavistin or *Trichoderma* prior to sowing. Ideally, the seedlings should be transplanted in the evening.

Additionally, a trellis structure should be constructed for climbing vegetables such as broad beans (Val), black-eyed peas (Chavali), bitter gourd, ridge and sponge gourd etc. and for flowering plants like Jai, Jui, and Chameli. These vines should be trained onto the trellis to ensure their robust growth, while simultaneously providing some shade to the other crops.

Vegetable crops suitable for cultivation in pots.....

Eggplant – Pusa Purple Cluster, Pusa Purple Long, Punjab Bahar

Chili – Pusa Jwala, Local Varieties, Jayanti

Fenugreek – Pusa Kasuri, Pusa Early Bunching

Tomato – Pusa Early Dwarf, Pusa Gaurav, Local Varieties

Okra – Varsha Uphar, Parbhani Kranti Spinach – Pusa Bharati, Pusa Jyoti, Local Varieties

Bitter Gourd – Arka Harit, Pusa Vishesh, Local Varieties

Indian Bean – Dasra, Dipali, Local Varieties, Lashkari Val

Cluster Bean – Pusa Sadabahar, Pusa Navbahar

Ginger – Local Varieties

**Flowering Plants for Terrace and Balcony Gardens –**

Flowering Plants: Marigold, Aster, Periwinkle (Sadaphuli), Chrysanthemum, Gaillardia, Tuberose (Nishigandha), Jasmine (Jai), Jasmine (Jui), etc.

Ornamental Plants: Aralia, Cyperus, Cactus, Begonia, Coleus, etc.

Fertilizer and Water Management –

Proper management of fertilizer and water in appropriate proportions is essential for the growth of the plants. Ideally, chemical-free fertilizers such as vermicompost, farmyard manure, or compost should be used to nourish the plants.

However, if the plants are still not growing properly, chemical fertilizers containing micronutrients such as nitrogen, potassium, phosphorus, iron, copper, etc. should be used in very small quantities. Furthermore, maintaining soil moisture is equally essential; therefore, crops should be watered regularly as per their requirements. During the summer season, green-colored shade nets should be utilized to protect the plants from intense sunlight.

Also you can use drip irrigation system. A drip system is an easy-to-use hydroponic system that can be quickly altered for different types of plants, which makes this a great system for any grower who plans to make regular changes. Drip system pumps the nutrient solution through the tube and drops onto plant roots via a network of drip lines. At the end of each tube is a drip emitter that controls the amount of nutrient solution provided to plants as per the need of individual plant.

Pest and Disease Management –

Infestations of various types of pests and diseases are frequently observed on seedlings. If such issues are detected, immediately contact the Department of Agriculture or the nearest Krishi Vigyan Kendra (Agricultural Science Center) to seek expert advice. Do not spray any unnecessary pesticides merely on the recommendation of a shopkeeper.

To avoid infestation of pests some amount of organic pesticides can be mixed in the soil. The plants can be sprayed with neem oil to control sucking pests which is a major problem in rooftop gardening. The neem oil is mixed in 10 litre of water with addition of 10 g of soap mixture and sprayed over affected vegetable plants. The spray made out of ginger, garlic and chilli paste diluted in water is also very effective in pest control.

**Crop Harvesting –**

Vegetables and flowers should be harvested as needed or according to the specific growth stage of the crop. If we cultivate a kitchen garden on our terrace or balcony in this manner, we can easily ensure a regular supply of nutritious vegetables, as well as flowers required for home decoration and religious rituals.

Government initiatives in promoting rooftop gardening -

State governments in some states under the Rashtriya Krishi Vikas scheme and Smart City development is offering 50% subsidy on seeds, fertilizers and farming equipment. House owners with a minimum of 50 to 300 square foot space in their balconies or backyard are eligible for availing 50% subsidy. The gardening and horticultural activities on the rooftops will help in improving the environmental conditions and restoring the climatic imbalance to an extent. Agriculture Skill Council of India (ASCI) conducts training programme on Rooftop Gardener, aims at building the following key competencies amongst the learner: Design and execute a rooftop garden as per the instructions received. Grow and maintain the condition of plants on a rooftop garden. Use and maintain the gardening tools, containers and other equipment. Monitor the plants and identify the potential damage due to insect, pests and diseases and learn how to control them. Practice health and safety at the work place: Well versed with health and safety measures in terms of personal as well as others safety and introduction to harmful practices of designing and execution. The type of rooftop garden design depends partly on your interest in gardening and maintenance, and on the environmental benefits you wish to achieve. Rooftop plantings can interact with the heat produced by the building. Vegetation can work to cool buildings by insulating and shading as well as improving urban air quality. Once a rooftop has been developed for gardening, it remains that way, regardless of design, model and size. A rooftop garden is an investment in peace of mind for people living in urban areas, providing hours of relaxation and reward in the form of nutritional supplementation to family.

A cropping pattern, which may prove helpful for kitchen garden under Indian conditions (except hill stations), is given below:

Plot no	Name of the Vegetable	Season
01.	Tomato and Onion, Radish, Beans, Bhendi	June – Sep, Oct.-Nov, Dec.-Feb. Mar. May



02.	Brinjal, Beans, Tomato, Amaranthus	June - Sep. Oct.-Nov June - Sep. May
03.	Chilli and Radish, Cowpea ,Onion (bellary)	Jun-Sep. Dec.-Feb. Mar.-May
04.	Bhendi and Radish, Cabbage, Cluster beans	Jun.-Aug. Sep.-Dec. Jan.-Mar.
05.	Bellary Onion, Beet root, Tomato	June-Aug. Sep.-Nov. Dec.-Mar. Apr. May
06.	Cluster beans, Brinjal and beet root	Jun.-Sep. Oct.-Jan.
07.	Bellary onion, Carrot, Pumpkin (small)	Jul.-Aug. Sep.-Dec. Jan.-May
08.	Lab lab (bush type) Onion, Bhendi, Coriander	Jun.-Aug. Sep.-Dec. Jun.-Mar Apr.-May





Modern Irrigation Techniques in Vegetable Farming

M. Vignesh¹

¹Ph. D Scholar, Department of Vegetable science, HC and RI, TNAU, Coimbatore,
Tamil Nadu, India - 641 003



ABSTRACT

Efficient water management is essential for sustainable vegetable production, especially in the face of increasing water scarcity and climate change. Modern irrigation techniques have emerged as innovative solutions to improve water use efficiency, enhance crop productivity, and reduce environmental impacts. Techniques such as drip irrigation, sprinkler systems, precision irrigation, and automated irrigation technologies are widely adopted in vegetable farming. These methods ensure optimal water delivery directly to plant roots, minimizing wastage and improving nutrient uptake. This article highlights various modern irrigation techniques, their advantages, and their role in sustainable vegetable cultivation.

Keywords: Drip irrigation, Precision farming, Water management, Vegetable crops, Sustainable agriculture

Introduction

Water is a critical input in vegetable farming, directly influencing plant growth, yield, and quality. Traditional irrigation methods often result in significant water losses due to evaporation, runoff, and inefficient distribution. With the growing demand for food and limited water resources, efficient irrigation practices are becoming increasingly important. Modern irrigation techniques focus on delivering the right amount of water at the right time and place. These methods help conserve water, improve crop productivity, and reduce labor costs. The adoption of advanced irrigation systems is essential for ensuring sustainable vegetable production under changing climatic conditions.



Importance of Efficient Irrigation in Vegetable Farming

Efficient irrigation plays a vital role in maintaining soil moisture and ensuring proper plant growth. Vegetables require consistent water supply due to their shallow root systems and high water demand. Inadequate or excessive irrigation can lead to poor growth, reduced yield, and quality deterioration. Modern irrigation systems help optimize water use by reducing wastage and improving water distribution. They also enhance nutrient use efficiency when combined with fertigation techniques. Efficient irrigation contributes to sustainable agriculture by conserving water resources and improving farm profitability.

Drip Irrigation System

Drip irrigation is one of the most efficient irrigation methods used in vegetable farming. It delivers water directly to the root zone of plants through a network of pipes and emitters. This method minimizes water loss due to evaporation and runoff. Drip irrigation improves water use efficiency and ensures uniform moisture distribution. It also reduces weed growth by limiting water supply to non-crop areas. Additionally, fertilizers can be applied through the system, enhancing nutrient availability. This technique is widely used for crops like tomato, cucumber, and capsicum.



Sprinkler Irrigation System

Sprinkler irrigation mimics natural rainfall by distributing water through overhead sprinklers. It is suitable for a wide range of vegetable crops and soil types. This system ensures uniform water distribution across the field. Sprinkler irrigation is particularly useful in areas with uneven terrain where traditional irrigation is difficult. It helps maintain soil moisture and reduces soil erosion. However, water loss due to evaporation and wind drift can be a limitation. Proper system design and operation can improve its efficiency.



Precision Irrigation Technologies

Precision irrigation involves the use of advanced technologies such as sensors, satellite data, and automation to optimize water use. Soil moisture sensors and weather-based systems help



determine the exact water requirements of crops. This technology ensures that crops receive water only when needed, reducing wastage and improving efficiency. Precision irrigation also supports data-driven decision-making, enhancing crop productivity. It is an important component of smart agriculture and sustainable farming systems.

Table 1. Comparison of Modern Irrigation Techniques in Vegetable Farming

Irrigation Method	Water Efficiency	Suitable Crops	Advantages	Limitations
Drip Irrigation	Very High	Tomato, cucumber	Saves water, reduces weeds	High initial cost
Sprinkler System	Moderate	Leafy vegetables	Uniform distribution	Evaporation loss
Precision Irrigation	Very High	All vegetables	Data-based irrigation	Requires technology
Surface Irrigation	Low	Traditional crops	Low cost	High water loss
Fertigation	High	Most vegetables	Efficient nutrient delivery	Maintenance required

Fertigation and Its Benefits

Fertigation is the application of fertilizers through irrigation systems, particularly drip irrigation. It allows precise delivery of nutrients directly to the plant root zone. This method improves nutrient use efficiency and reduces fertilizer losses. Fertigation ensures uniform nutrient distribution and enhances crop growth and yield. It also reduces labor and input costs. Proper management of fertigation systems is essential to avoid clogging and ensure optimal performance.

Use of Automation and Smart Irrigation Systems

Automation in irrigation involves the use of timers, sensors, and control systems to manage water application. Smart irrigation systems adjust water supply based on real-time data such as soil moisture and weather conditions. These systems reduce manual intervention and improve



irrigation efficiency. Automation helps save water, energy, and labor while ensuring optimal crop growth. Integration of mobile applications and IoT devices further enhances system efficiency and monitoring.

Advantages of Modern Irrigation Techniques

Modern irrigation techniques offer numerous benefits in vegetable farming. They significantly improve water use efficiency and reduce wastage. These methods enhance crop yield and quality by ensuring optimal water and nutrient supply.

They also reduce labor requirements and operational costs. Additionally, modern irrigation systems help in conserving water resources and protecting the environment. Their adoption is crucial for sustainable agricultural development.

Challenges in Adoption of Modern Irrigation

Despite their benefits, the adoption of modern irrigation techniques faces several challenges. High initial investment costs and lack of awareness among farmers are major constraints. Technical knowledge and maintenance requirements can also limit adoption. Small and marginal farmers may find it difficult to invest in advanced systems. Government support, subsidies, and training programs are essential to promote adoption. Addressing these challenges can help expand the use of modern irrigation technologies.

Future Prospects of Irrigation in Vegetable Farming

The future of irrigation lies in the integration of advanced technologies such as artificial intelligence, remote sensing, and IoT. These innovations will further improve water use efficiency and crop productivity. Sustainable irrigation practices will play a key role in addressing water scarcity and climate change challenges. Research and development efforts are needed to make these technologies affordable and accessible to farmers. Modern irrigation will continue to be a cornerstone of sustainable vegetable production.

Conclusion

Modern irrigation techniques have revolutionized vegetable farming by improving water use efficiency and crop productivity. Methods such as drip irrigation, sprinkler systems, and precision irrigation offer sustainable solutions to water management challenges. Adoption of these techniques is essential for ensuring food security and environmental sustainability. With



proper support and technological advancements, modern irrigation systems can significantly enhance vegetable production. Sustainable water management will be key to the future of agriculture.

References

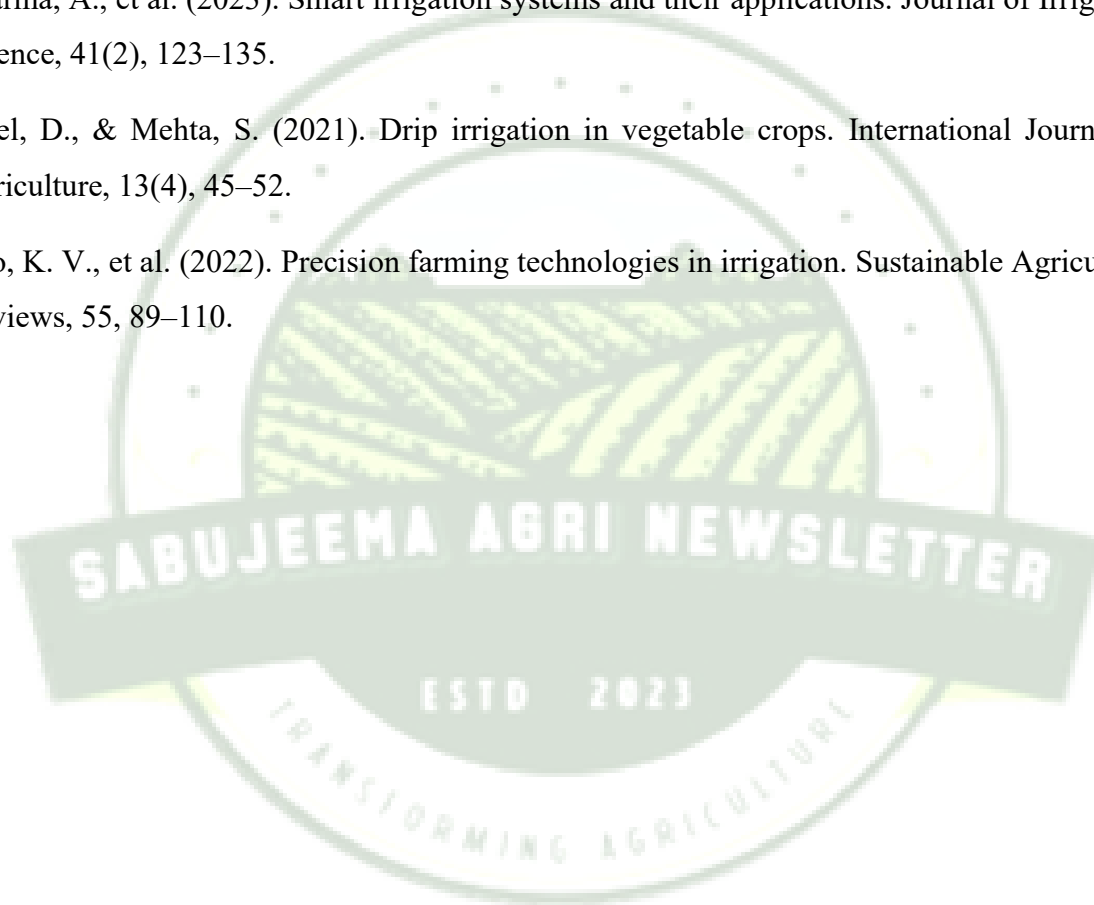
FAO. (2021). Water management in agriculture. Food and Agriculture Organization.

Kumar, R., & Singh, P. (2022). Modern irrigation techniques for sustainable agriculture. *Agricultural Water Management*, 261, 107345.

Sharma, A., et al. (2023). Smart irrigation systems and their applications. *Journal of Irrigation Science*, 41(2), 123–135.

Patel, D., & Mehta, S. (2021). Drip irrigation in vegetable crops. *International Journal of Agriculture*, 13(4), 45–52.

Rao, K. V., et al. (2022). Precision farming technologies in irrigation. *Sustainable Agriculture Reviews*, 55, 89–110.





Biotechnological Approaches in Vegetable Crop Improvement

M. Vignesh¹

¹Ph. D Scholar, Department of Vegetable science, HC and RI, TNAU, Coimbatore, Tamil Nadu, India - 641 003



ABSTRACT

B iotechnology has revolutionized vegetable crop improvement by offering advanced tools to enhance yield, quality, and stress tolerance. Traditional breeding methods are time-consuming and limited by genetic variability, whereas biotechnological approaches enable precise and rapid development of improved varieties. Techniques such as genetic engineering, tissue culture, marker-assisted selection, and genome editing have significantly contributed to vegetable crop enhancement. These methods help in developing disease-resistant, climate-resilient, and nutritionally enriched vegetable varieties. Biotechnology also plays a vital role in ensuring food security and sustainable agriculture. This article highlights various biotechnological approaches and their applications in vegetable crop improvement.

Keywords: Biotechnology, Genetic engineering, Tissue culture, Vegetable crops, Crop improvement

Introduction

Vegetable crops are an essential component of human diets, providing vital nutrients such as vitamins, minerals, and antioxidants. However, their productivity is often limited by biotic and abiotic stresses, poor genetic potential, and environmental constraints. Traditional breeding methods have contributed significantly to crop improvement, but they are time-consuming and less precise. Biotechnological approaches offer innovative solutions to overcome these challenges. These techniques allow the manipulation of plant genetic material for desired traits such as higher yield, disease resistance, and improved quality. The integration of biotechnology with conventional breeding has accelerated the development of superior vegetable varieties. As global food demand increases, biotechnology plays a crucial role in ensuring sustainable vegetable production.



Plant Tissue Culture Techniques

Plant tissue culture is one of the most widely used biotechnological tools in vegetable crop improvement. It involves the in vitro cultivation of plant cells, tissues, or organs under controlled conditions. This technique allows rapid multiplication of disease-free planting material. Micropropagation ensures uniformity and high-quality plant production. Tissue culture is also used for the conservation of germplasm and production of haploids and doubled haploids. It plays a key role in the development of improved varieties with desirable traits. This technique is widely applied in crops like potato, tomato, and banana.

Genetic Engineering in Vegetables

Genetic engineering involves the direct transfer of genes from one organism to another to introduce desirable traits. This technique allows the development of genetically modified (GM) vegetables with improved characteristics such as pest resistance, herbicide tolerance, and enhanced nutritional quality. Examples include Bt brinjal and virus-resistant tomatoes. Genetic engineering helps reduce crop losses and dependence on chemical pesticides. It also improves crop productivity and quality. However, concerns related to biosafety and public acceptance need to be addressed for wider adoption.

Marker-Assisted Selection (MAS)

Marker-assisted selection is a modern breeding technique that uses molecular markers to identify desirable traits in plants. It helps in selecting plants with specific genes without waiting for the trait to be expressed. MAS accelerates the breeding process and increases the accuracy of selection. It is widely used for developing disease-resistant and stress-tolerant vegetable varieties. This technique reduces the time and cost involved in conventional breeding. It is particularly useful in improving complex traits controlled by multiple genes.

Genome Editing Technologies

Genome editing technologies such as CRISPR-Cas9 have revolutionized crop improvement. These tools allow precise modification of plant DNA without introducing foreign genes. Genome editing can be used to enhance yield, improve nutritional quality, and increase resistance to stresses. This technology is faster and more efficient than traditional genetic engineering. It also has fewer regulatory concerns in some countries. Genome editing holds great potential for developing climate-resilient vegetable crops. Continued research is needed to explore its full potential.



Role of Biotechnology in Stress Tolerance

Biotechnology plays a significant role in developing vegetable crops that can withstand abiotic stresses such as drought, salinity, and temperature extremes. Genetic engineering and molecular breeding help introduce stress-tolerant traits into crops. Biotechnological approaches enhance the plant's ability to adapt to adverse environmental conditions. They improve physiological and biochemical responses under stress. This leads to better growth and productivity even under unfavorable conditions. Such advancements are crucial for sustainable agriculture.

Table 1. Biotechnological Tools and Their Applications in Vegetable Crops

Technique	Application	Benefits	Example Crops
Tissue Culture	Micropropagation	Disease-free plants	Potato, banana
Genetic Engineering	Trait improvement	Pest resistance	Brinjal, tomato
Marker-Assisted Selection	Gene identification	Faster breeding	Tomato, pepper
Genome Editing	DNA modification	Precision breeding	Lettuce, cabbage
Biofortification	Nutritional enhancement	Improved nutrition	Carrot, spinach

Nutritional Enhancement of Vegetables

Biotechnology is also used to improve the nutritional quality of vegetables through biofortification. This involves increasing the levels of essential nutrients such as vitamins, minerals, and antioxidants. Genetic engineering and breeding techniques help develop nutrient-rich vegetable varieties. These crops contribute to better human health and nutrition. Biofortified vegetables play an important role in combating malnutrition and hidden hunger. This approach supports global food and nutritional security.



Challenges and Ethical Considerations

Despite its advantages, biotechnology faces several challenges and ethical concerns. Public acceptance of genetically modified crops remains a major issue. Biosafety regulations and environmental risks need to be carefully addressed. High research costs and technical expertise requirements also limit its adoption. There is a need for awareness and education among farmers and consumers. Proper regulatory frameworks and policies are essential for safe and effective use of biotechnology.

Future Prospects of Biotechnology in Vegetable Crops

The future of biotechnology in vegetable crop improvement is promising. Advances in genomics, proteomics, and bioinformatics are opening new possibilities. Integration of biotechnology with precision agriculture can further enhance productivity. Research is focused on developing climate-resilient, high-yielding, and nutrient-rich vegetable varieties. Collaboration between scientists, policymakers, and farmers is essential for successful implementation. Biotechnology will continue to play a key role in sustainable agriculture.

Conclusion

Biotechnological approaches have significantly transformed vegetable crop improvement by providing innovative and efficient solutions. Techniques such as tissue culture, genetic engineering, and genome editing have enhanced crop productivity, quality, and stress tolerance. These advancements are essential for meeting the growing food demand and ensuring sustainability. However, challenges related to cost, regulation, and public acceptance must be addressed. With proper implementation, biotechnology can contribute to a more resilient and productive agricultural system.

References

- Ricroch, A., et al. (2022). Plant biotechnology for sustainable agriculture. *Plant Biotechnology Journal*, 20(5), 879–890.
- Jaganathan, D., et al. (2021). CRISPR for crop improvement. *Trends in Plant Science*, 26(4), 310–320.
- Kumar, S., & Sharma, R. (2023). Advances in vegetable biotechnology. *Journal of Horticultural Science*, 18(2), 95–110.



Significance of Biofortified Crops in Human Nutrition and Food Security

Dr Sasanka Lenka¹, Dr Paritosh Murmu², Rudra Mahalik³, Swagatika Mallik⁴, and Binapani Taria⁵

¹Sr. Scientist and Head, Krishi Vigyan Kendra, Umerkote, Nabarangpur-764073,

²Scientist (Agronomy), ³SMS, Plant Protection, ⁴SMS, Eng, ⁵Farm Manager, Krishi Vigyan Kendra, Umerkote, Nabarangpur-764073



Backdrop

The planet's burgeoning population and proliferating food demand put pressure on healthy food for better human nutrition. However, our current food chain systems are inadequate to meet the growing nutritional demands of human beings. Nutritious enriched foods are essential for human health and development. It is a basic need of humans and a prerequisite to lead a healthy life (Shamah and Salvador, 2006). A proper growth and development balanced diet with macro and micronutrients is required for everyone. Over the years, the current food chain system has gradually lost the nutritive food value and taste. To perform the day-to-day activities, healthy food and water. The present foods produced in the market are contaminated with various chemicals and pesticide residues which create an abundant health hazard. As per the data available, more than 3 billion people, mainly in Africa, Latin America and Asia can't afford a diet to meet their nutritional requirements. With this view, biofortified crops are vital in India because they can help address malnutrition, a major health issue that affects people of all ages. Biofortified crops can help the poor and rural people who often consume staple crops and have limited access to higher-value foods (Kiran *et al.*, 2022). Biofortification is a process or a method for getting nutrient-enriched food through genetic engineering, modern techniques plant breeding and integrated crop management (ICM) practices that provide enough macro and micronutrients to human beings. The word biofortification is derived from two words, i.e., bios and fortificare, which means life and to make strong.

Biofortification increases the well-being of human beings as well as strengthens the human value in society. It is an improved version of crop genetics that boosts crop production as well as increases the vitamins and minerals content of crops. The supplementation of nutritive value

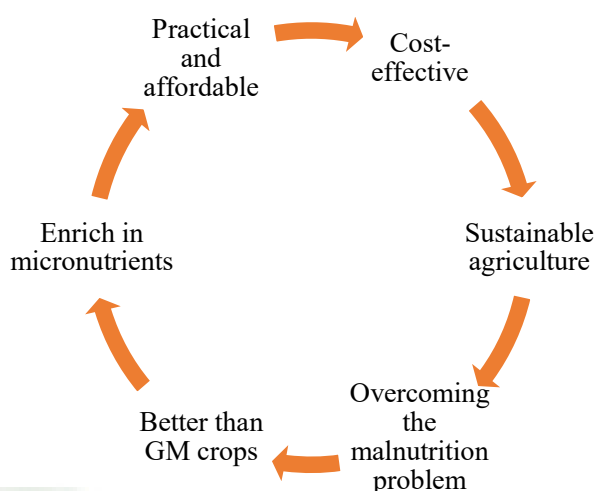


in crop varieties increases the demand and the adoption of those varieties by farmers can ensure enough calories to the hunger people. The supplementation of essential nutrients for more vigour in human society and life spans. Good health comes only from a balanced diet. Intake of diversified food crops is beneficial for maintaining proper human health. Consumption of only one type of food leads to deficiency and ultimately some chronic disorders (Kiran *et al.*, 2022). The accessibility and consumption of various types of biofortified foods make life stronger and healthier to lead a better life. Over the past decade, great progress has been made concerning the use of biotechnology and plant breeding to augment the biofortified, nutritionally enriched food crops.

Bio-fortification in Zn-enriched staple crops like rice, wheat, lentils, sorghum, cowpeas, maize, wheat sorghum, lentils, pearl millet and orange, sweet potatoes, cassava, squash, and Fe-enriched beans, essential micronutrients benefit the world's poor people in combating nutritional disorders and chronic diseases. Most of the millet crops have coping mechanisms to overcome diseases, pests and droughts. A few crops and varieties of staple crops are more resilient to biotic and abiotic stress and also give higher yields. But if we consider the case of rural areas which consist of poor and middle-class families, in that situation availability of quality foods is neither accessible nor affordable. These populations are always dependent on staple crops for their growth and development. However, the current food systems are not adequate to bridge the gap in vitamins and minerals for human beings. Over the years, policymakers and the government. Private agencies and NGO peroneal have given more emphasis on biofortified crops. Rice is one of the major subsistence and dominant crops that somehow address the issue of vitamins and minerals that help to maintain proper human health. The recent development of biofortified crops paved the way to challenge these problems. The biofortification process can boost the vitamin and mineral content in staple crops through innovative biotechnology and plant breeding techniques. Major interventions such as dietary diversification and food supplementation are being practised and adopted. The main 19 vitamins and minerals are considered essential for human health. Both macro and micronutrients play an imperative role in human growth and development. However, the availability or deficiencies of iodine (I), Fe, Zn, and vitamin A cause several health disorders. Unhygienic food and current living standards cause several health disorders among human beings. Daily, we require macronutrients like carbohydrates, proteins, and fat for more energy

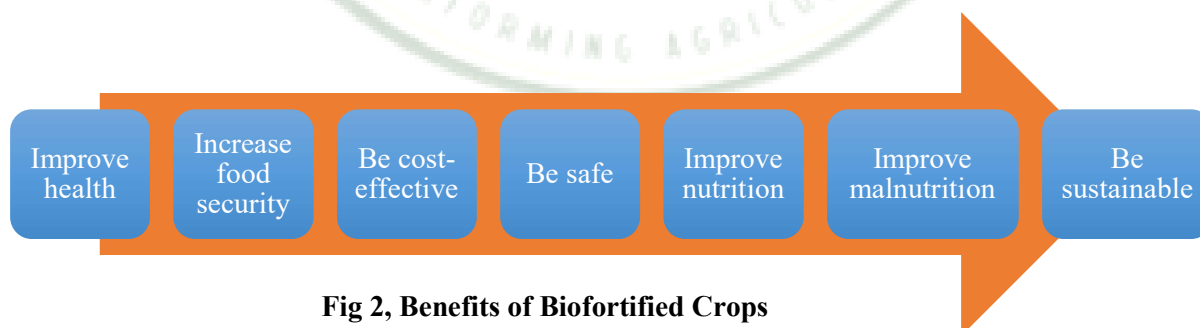


and to perform better work and movement. As India is a developing country, it has immense potential for biofortification. The major advantages of biofortification are cost-effective, sustainable agriculture, overcoming the malnutrition problem, better than GM crops, enriched in micronutrients and practical and affordable. Similarly, micronutrients like minerals and vitamins are essential for cell growth, metabolism, the human immune system of human beings, and the possible solution for malnutrition and hunger.

**Fig 1, Advantages of Biofortified Crops**

2.0 Rationale of Biofortification

Biofortification is a process that improves the nutritional quality of food crops to reduce vitamin and mineral deficiencies in human beings. It can be done through a variety of techniques, including conventional plant breeding, improved agronomic practices, and modern biotechnology. Biofortification is a possible solution to mitigate micronutrient deficiencies among people in both rural and urban areas across the world. The increasing population and climate change are the main impediments to achieving food security. Over the years the effect of climate change has caused various adverse situations like drought, floods, cyclones, erratic and uneven rainfall, increasing temperatures and rising sea levels. Biofortifying crops is a way to improve the nutritional quality of food and help address malnutrition, especially in

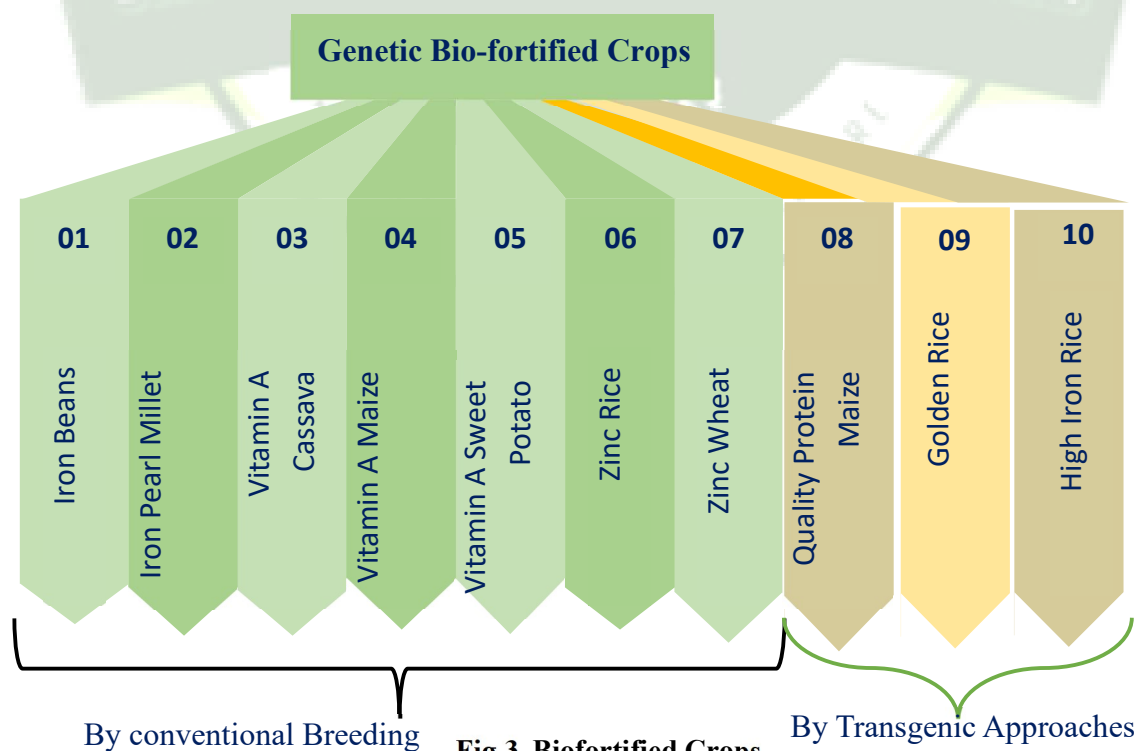
**Fig 2, Benefits of Biofortified Crops**

developing countries like India. The major rationales for biofortified crops and their benefits are as follows:



Biofortification is a process of enriching nutrients in the various crops through improved methods of breeding techniques and genetic engineering. It is different from conventional fortification. Biofortification is more scientific and has more authenticity and accuracy which is far better than conventional fortification. Biofortification is the only solution for getting nutrient-rich crops for long-term sustainability and it is affordable for small and marginal farmers. The biofortified crops are more beneficial for young children as well as adolescent girls and women for their daily requirement of micronutrients and minerals. The crops have good keeping quality and storage ability. Biofortification can help reduce vitamin and mineral deficiencies, leading to diseases like anemia, beriberi and rickets. Biofortification increases the quantity of vitamins, minerals, and other nutrients in crops, which can help people get the calories and nutrients they need for good health. Biofortification is an economical method that involves the plants synthesizing or accumulating nutrients, rather than adding them through artificial means.

Developing nutritionally enhanced plants resistant to abiotic stresses presents a viable solution to these future challenges (Bazuin, *et al.*, 2011; Kershen, 2010). The design of conventional plant breeding programs to improve micronutrient content has also proven to be successful; however, there are limitations concerning the amount of variability in the plant gene pool and the time needed to generate cultivars with the desired traits (Hirschi, 2009; Nestel, 2006).

**Fig 3, Biofortified Crops**



Biotechnology is a more cost-effective method used in the production of biofortified crops for long-term benefits and sustainability. Similarly, it is used for transgenic crops to produce high protein. Recently, genome editing has focused on nuclease-based forms of engineering, such as the TALENS (transcription activator-like effector nucleases) or the CRISPR (clustered regularly interspaced short palindromic repeats)/CRISPR-associated (Cas) systems and concerns the creation of precise incisions, mutations and substitutions in plant and other eukaryotic cells (Gaj *et al.*, 2013). This technology will help enhance food crops to improve global nutritional status. As a result, genome editing may very well help plant biotechnologists avoid the same public controversy that was raised by using GMOs (Puchta *et al.*, 2013). Now crops like rice, maize, sorghum, barley, tobacco and soybean are used in genome editing. The objectives of biofortified crops are to improve the nutritional content of staple foods, such as rice, wheat, maize, and pearl millet. It improves the quality of crops and also increases the protein content in various crops. In oilseed crops, it improves vitamins, minerals and oil content. Biofortification is a sustainable and cost-effective agricultural strategy that uses conventional plant breeding techniques to achieve these objectives.

3.0 Techniques of Biofortification

Biofortification is a method of increasing the nutritional value of crops through the addition of essential nutrients. The foremost techniques used for the biofortification of crops are mentioned below.

1. **Agronomic practices:** Agronomic practices are the methods of application of fertilizers in crops to increase the micronutrient content in crop plants. The use of micronutrient fertilizers enriched the nutritional status of crops as well as supplemented the nutritional requirements of human beings for normal growth and development.
2. **Conventional plant breeding:** Conventional plant breeding includes the traditional breeding methods to improve the genetic variations and maintain the quality of the foods. That food is enriched with minerals and vitamins to bridge up gap in nutritional requirements. Biofortified crops have more nutritional value and address the current requirement of current hours. It is a food naturally more nutritious than adding nutrient supplements to the foods and also improves the yield and food quality. It is a process of crossing varieties over many generations and finally obtaining the high-nutrient-content food.



3. **Genetic engineering/modification:** Genetic modification of plants involves adding a specific stretch of DNA into the plant's genome, giving it new or different characteristics. This could include changing the way the plant grows or making it resistant to a particular disease.
4. **Transgenic crops:** A critical method of biofortification that can also extend the shelf life of fruits and vegetables. Genetically modified (GM) crops also known as transgenic crops and plants, have been modified to have certain traits, such as herbicide tolerance or insect resistance. Transgenic crops are used for a variety of purposes, including animal food, making cooking oil, and resisting browning. Some examples of transgenic crops include soybean, maize, cotton, canola, potato, corn, papaya, squash, pumpkin, and alfalfa.

Biofortified foods are most beneficial for the vulnerable community who are not able to consume two meals per day. What food do they consume that is deficient in vitamins and

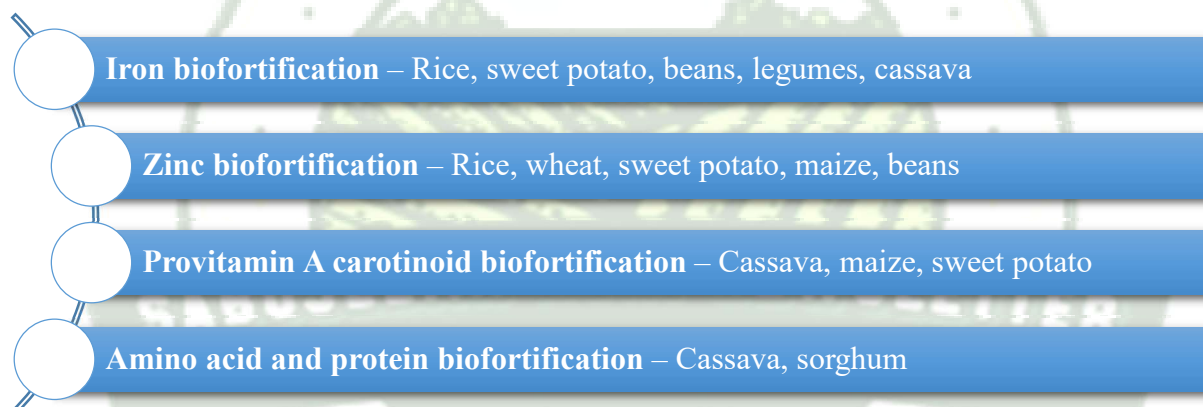


Fig 4, Biofortification Food Crops

minerals. Biofortified foods are essential for young children, adult women, pregnant women, breastfeeding women and older adults. Balanced, healthy, nutritious enriched food and a diverse diet are required to lead a healthy life.

4.0 Importance of Biofortification

Over the years Govt has taken lots of initiatives to eradicate poverty and hunger in India. More schemes and programmes were implemented based on the ground reality to benefit the vulnerable people. But the growth is very slow as was expected. Sometimes the government faces many challenges in providing adequate food, at least two meals a day, to the malnourished and hungry people. The burgeoning population of India requires food to meet their daily needs.



The Green Revolution and related movements in India were focused on eradicating hunger from the country. Still, more food is required to feed the nation. Biofortification is one of the key initiatives to address the healthy food requirements of poor people. However, the current focus is on increasing the nutrient-rich food availability in the market to meet the optimal nutritional index of the food consumption habits of people. Scorn having 'enough food to eat', many people are not able to intake enough nutrients in their food dietary pattern. This causes the problem of starvation or hidden hunger. Starvation means not having enough food to consume in day-to-day life. Starvation can be solved by consuming biofortified food crops.

We have to change our current approach based on the needs of the hour to enhance agricultural productivity, introduce new biofortified crops, promote sustainable agriculture, strengthen a social safety net and reduce food waste. The Green Revolution has substantially increased the food grain production in India to fulfil the demand for food grain. As of now, our food demand has increased manifold. But somehow, we are on the back foot to meet the food requirement with a calorific value of essential vitamins and minerals towards nutritional security. Biofortified crops provide a cost-effective, nutrient-rich, sustainable and long-term revenue by carrying more micronutrients to the rural population. The market potential for biofortified crops should be explored and should be available in the market. So that consumers can easily purchase from the market and consume for their lives. The government need to promote those biofortified crops under different schemes and programmes so that those foods can be available in the market.

Biofortified staple foods cannot deliver as high a level of minerals and vitamins per day as supplements or industrially fortified foods, but they can help by increasing the daily adequacy of micronutrient intakes among individuals throughout the lifecycle (Bouisset *et al.*, 2011). Biofortified cannot alone fulfil the requirement of micronutrient deficiencies but somehow bridge the gap in the requirement of the growing population. For instance, according to the World Health Organisation (WHO) estimation, biofortification could help cure two billion people suffering from iron deficiency-induced anemia (Mc Lean *et al.*, 2009). Sustainable Development Goal 2 envisages ending all forms of starvation and malnutrition by 2030. Ensure that people have enough nutritious food for the whole year. Some of the other importance of biofortification are as follows:

- ➔ Biofortification helps to improve the health condition and nutritional requirements of people.



- ➔ Biofortification crops are more resilient to biotic and abiotic stresses and give higher yields.
- ➔ It supplies more micronutrients, vitamins and minerals for good health and vigour.
- ➔ It helps farmers to get higher profits, and its availability in the market has huge potential to percolate to the poorest and most disadvantaged in society.
- ➔ The crops are cost-effective for producers and consumers during participatory research, replication, and scaling up production.
- ➔ Biofortification is done through various plant breeding methods and as an alternative source of GM crops. GM crops have many restrictions compared to biofortified crops.
- ➔ Biofortification has ample scope, is cost-effective and meets the nutritional and starvation challenges in India.

The findings of various studies, impact assessments and reports show that India faces many challenges in the form of nutrition and starvation in the different geographic situations in the country. parts of the country. The poor nutrition and the health condition of poor people are affected by Anemia and many health disorders. Govt has taken lots of initiatives under different flagship programmes and schemes. The major sources of nutrients from vegetables are as follows;

Table 1, Sources of nutrients from vegetables (Food and Nutrition Board, 2013)

Nutrients	Vegetables
Carbohydrate	Sweet potato, potato, cassava
Protein	Pea, lima bean, French bean, cowpea
Vitamin A	Carrot, spinach, pumpkin
Vitamin B1	Tomato, chilli, garlic, leek, pea
Vitamin C	Chilli, sweet pepper, cabbage, drumstick
Calcium	Hyacinth bean, amaranthus, palak
Iron	Amaranthus, palak, spinach, lettuce, bitter gourd
Phosphorous	Pea, lima bean, taro, drumstick leaves



Vitamin B5	Palak, amaranthus, bitter gourd, pointed gourd
Iodine	Tomato, sweet pepper, carrot, garlic, okra
Sodium	Celery, green onion, Chinese cabbage, radish

5.0 Biofortification in Different Staple Crops

5.1 Biofortification of Cereals

5.1.1 Rice

Rice is the main staple food crop, giving rice biofortification a huge potential for alleviating malnutrition globally. Biofortified “Golden Rice” has huge potential for farmers to cultivate it in their farmland for higher profits. Biofortified rice varieties are enriched with high protein (more than 7%) and Zn, which prevents various diseases like Corona. It is also cost-effective for farmers.

Golden Rice is a natively modified rice crop that has beta-carotene and other carotenoids in the grain. Beta carotene is supplemented with Vitamin A and carbohydrates, after digestion it adds value in the form of vitamin A to the human body. The main foundation of Golden Rice was formed from maize genes. Beta carotene gives a golden yellow colour to the rice variety. The deficiency of vitamin A causes night blindness by making the cornea very dry, thus damaging the retina and cornea. β -carotene is the precursor of the vitamin A molecule, absent from the grain of cereals such as rice. As a result, people having monotonous diets are at risk of vitamin A deficiency. The golden rice was developed by the research group of Ingo Potyus. This transgenic crop was engineered with two genes from other organisms (daffodil and the bacterium *Erwinia uredovioia*) which reconstitute the carotenoid biosynthetic pathway within the rice genome (Tang *et al.*, 2009). White rice (i.e., polished rice) lacks many vital nutrients including beta carotene while Golden Rice contains them in significant quantities. Golden Rice can also be considered a form of biofortified rice enriched with Zn. Golden rice can produce levels of β -carotene that are up to 35 $\mu\text{g/g}$ of dry rice (Tanumihardjoet *al.*, 2010), 130–200 g of deuterium-labelled. Golden rice provides 0.99–1.53 mg β -carotene to humans. Currently, there is no cultivation or commercialisation of Golden Rice in India.



5.1.2 Wheat

Wheat is the second most important cereal crop in different parts of the World. It is the main food crop in the north and north-western parts of the country. Wheat production in India accounts for about 14% of the world's total production and is the second-largest producer in the world. Wheat grain is the major contributor to the human diet. It provides many nutrients and minerals like Zn, Mg, Fe, Se, Mn, proteins and vitamins. India produces approximately 110 MT of wheat every year where the range of Fe concentrations of 20–60 mg kg⁻¹ and Zn concentrations of 15 to 35 mg kg⁻¹ was tested.

5.1.3 Maize

Out of the maize-growing countries, India ranks 4th in terms of area and 7th in production, 4% of the world's maize area and 2% of total production. It is one of the important staple crops in many countries but it is also known as a cash crop. Application of Zn in the method of seed priming, foliar spray, or incorporation in the soil enhances the germination of maize seed, healthy seedlings and tolerance against biotic and abiotic stresses. International organisations like CIMMYT reported out 1000 maize lines, and most of the maize lines have high concentrations of Zn, Fe, and provitamin A (15–35 mg kg⁻¹ Zn, an average of 20 mg kg⁻¹ Fe, and about 0–15 mg kg⁻¹ total provitamin A).

5.1.4 Pearl Millet

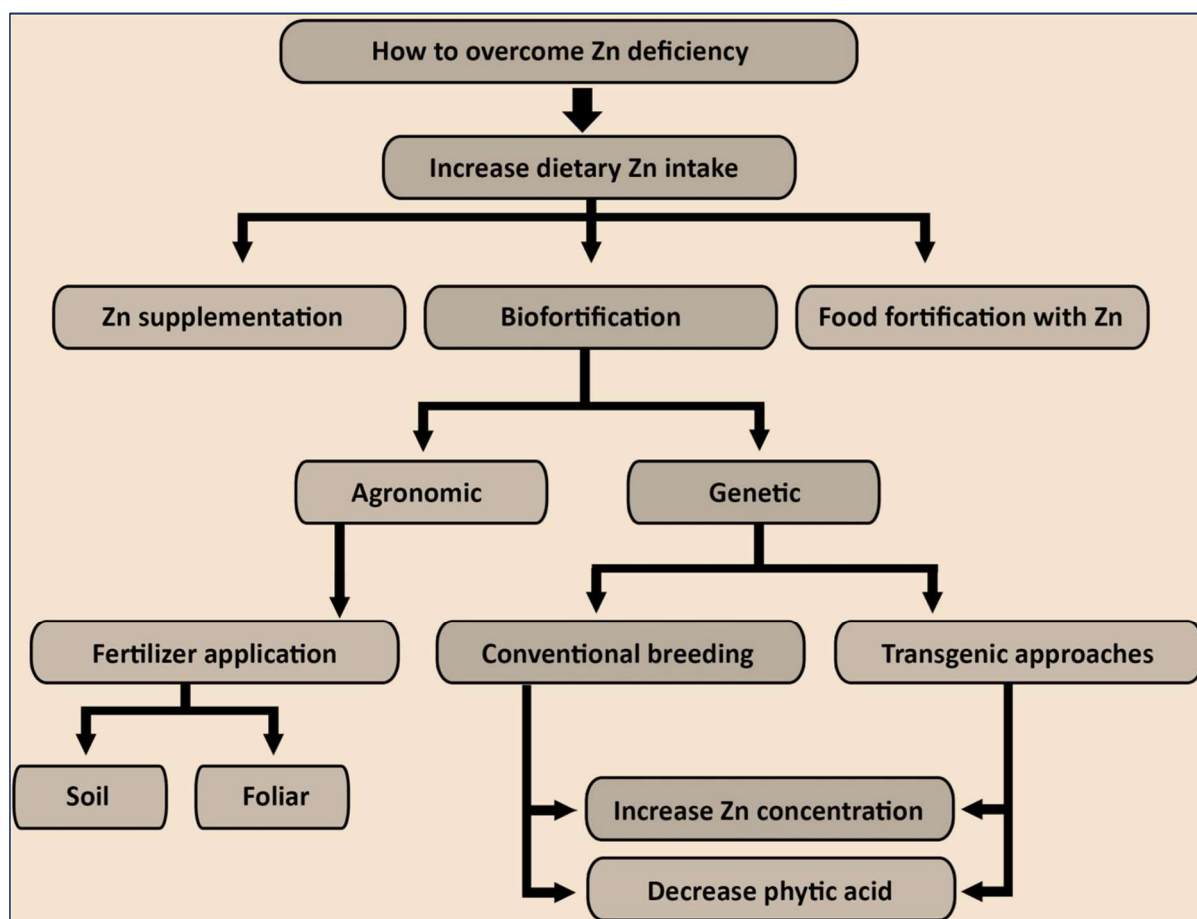
Pearl millet/ Bajra is mainly grown in the Kharif and Rabi season cereal crop in the arid and semi-arid tropical regions of Asia and Africa. It is used as a staple food for humans and fodder for animals. Earlier it was poor men's food, and now it is rich men's food due to protein and minerals. Pearl millet is a widely grown millet across the globe. Millions of people prefer a food that contains rich sources of micronutrients like Zn and Fe to wheat and rice. The micronutrient concentration of Fe (35–116 mg kg⁻¹), Zn (21–80 mg kg⁻¹), and protein (6–18%). Pearl millet has great genetic variation (30–140 mg kg⁻¹ Fe and 20–90 mg kg⁻¹ Zn). In India, open-pollinated pearl millet varieties (Dhanashakti) and hybrids (ICMH 1202, ICMH 1203, and ICMH 1301) with high concentrations of iron (70–75 mg kg⁻¹) and zinc (35–40 mg kg⁻¹) have been introduced.

Zn Availability: Zinc (Zn) is one of the micronutrients essential for the metabolic activities of humans, animals, and plants. Phytic acid (PA) has the power to bind zinc and other minerals as a known zinc absorption inhibitor and is predominant in most cereals.



Since phytic acid can be effectively degraded by microbial phytase enzymes, increasing mineral availability. This approach has been used in corn (Gao *et al.*, 2013). So the transgenic corn that expresses phytase derived from *Aspergillus niger* has been used in the degradation of phytic acid, as compared to conventional corn that needs to be supplemented with commercially used phytases.

Fig 5, Schematic diagram of fortification of Zinc deficiency



A triple-vitamin-fortified maize which expresses high amounts of β -carotene, ascorbate, and folate has been developed in the endosperm through metabolic engineering (Mugodeet *al.*, 2014). Mainly the transgenic seeds confined 169-fold the normal amount of β -carotene, 6-fold of ascorbate and double of folate in produced crops. Crops such as these can offer far more nutritional benefits to human beings (Jeong *et al.*, 2008).

Gliadins (which cause celiac disease) and amino acids are lowered in maize and wheat. The genetically altered wheat crop has dough-making quality and tastes good. Biofortified wheat provides more options for the proportion of the population who are gluten-sensitive or



intolerant, and can also provide higher levels of micronutrients, such as iron and zinc, to those in developing countries who use wheat as a staple food (Gill *et al.*, 2014; Borrillett *et al.*, 2014).

Zinc (Zn) is essential for biofortification. Zinc (Zn) deficiency causes stunted growth, poor immunity, impairments in mental development and birth complications. Radiolabeled Zn is taken up by the roots, translocated to shoots and accumulates in the wheat grain (Grillet *et al.*, 2014; Cakmak, 2009). Cakmak (2010) demonstrated that increasing the nitrogen supply in the soil can stimulate the root-to-shoot translocation of Zn and enhance its accumulation in wheat grain, possibly via increasing the abundance of transporter proteins in the presence of nitrogen (Cakmak, 2010).

5.2 Biofortification of Non-Cereals

Many non-cereal crops have huge potential to ensure food security across the world, especially in African countries. Both agronomic and genetic biofortification techniques apply to non-cereal crops. The details of the crops are as follows:

5.2.1 Cassava

Cassava is a staple food having a good source of vitamin C, thiamine, riboflavin, and niacin. However, it has low concentrations of Zn, I, Fe, and vitamin A. The leaves of cassava are also edible after cooking and they contain up to 25% protein. However, the cassava root does not deliver the same nutritional value as other tuber vegetables. Hence, biofortification is required for the cassava crops to enrich them with Fe, Zn, I and vitamin A that help to reduce micronutrient deficiencies. It has the power to manage stress conditions and improve poor soil.

5.2.2 Potato

Potato (*Solanum tuberosum*) is one of the important vegetable crops known for its source of energy for all age groups. Potatoes have great potential to improve human nutrition as well as have economic value through various biofortification strategies. Potatoes are a source of beta-carotene and is very popular among all categories of people.

5.2.3 Sweet Potato

Most sweet potato varieties have higher beta-carotene. Sweet potatoes are a healthy root vegetable chock full of antioxidants that protect your cells from damage. Sweet potatoes are rich in vitamins and minerals, including vitamin A, vitamin C, potassium, dietary fibre, and



zinc. The sweet potato nutrients are excellent for the eyes, your gut and immune system. Biofortification is required for white-fleshed varieties to orange-fleshed varieties. Sweet potato varieties contain 32 mg kg⁻¹ to 100 mg kg⁻¹ beta-carotene.

5.2.4 Common Beans

The common bean (*Phaseolus vulgaris*) is an herbaceous annual plant grown across the world. Mainly, the beans are used as food for their edible dry seeds or green, unripe pods. Its leaf is also occasionally used as a vegetable, and the straw as fodder. The beans are a rich source of amino acids like threonine, valine, leucine, isoleucine, and lysine. The nutritive value is considerably small due to low concentrations of the amino acids methionine and cysteine. Biofortification can enrich the vitamins and minerals.

6.0 Nutritional Factors

Protein: Protein is a nutrient essential for body growth, repairing cells, and tissue and performing our day-to-day activities properly. Protein is found in a wide range of foods, and you must get enough protein in your diet every day. How much protein you need from your diet varies depending on your weight, gender, age and health. Humans require 0.66 g of protein per 1 g/kg body weight/day to meet the requirement for proper growth and development. The deficiency leads to disorderly physical functioning, intellectual development and even mortality.

Lsine: Lysine, or L-lysine, is an essential amino acid, meaning it is necessary for human health, but the body cannot make it. You have to get lysine from food or supplements. Amino acids like lysine are the building blocks of protein. Lysine is an α -amino acid that is a precursor to many proteins. The daily average lysine requirement is 30 mg/kg body weight/day for adults, but for children, it is 35 mg/kg body weight/day for ages up to 12 years. Its deficiency leads to anaemia, fatigue, dizziness, delayed growth and loss of appetite.

Tryptophan: Tryptophan is an amino acid needed for normal growth in infants and for the production and maintenance of the body's proteins, muscles, enzymes, and neurotransmitters. It is an essential amino acid. This means your body cannot produce it, so you must get it from your diet. Simply, it is a building block of proteins and metabolic functions. Tryptophan is required in men is 4 mg/kg body weight/day in adults and 4.8 mg/kg body weight/day in children (3-10 yr). Its deficiency leads to depression, anxiety and impatience.



Iron: Iron is a mineral that the body needs for growth and development, as well as the proper functioning of muscle and brain. The body uses iron to make haemoglobin, a protein in red blood cells that carries oxygen from the lungs to all parts of the body, and myoglobin, a protein that provides oxygen to muscles. Sometimes the body also needs iron to make some hormones. The average requirement of iron for non-pregnant and non-lactating women is 1460 µg/g, while it is 500µg/g per day for children up to 4-6 yr. Iron deficiency causes anaemia, affects overall growth and development and mild mental retardation in human beings.

Zinc: Zinc is a nutrient found throughout your body, and it helps to strengthen the immune system and metabolic function. Zinc is also important to wound healing and your sense of taste and smell. Zn serves as a cofactor in as many as 300 enzymes required for human metabolism and has a vital role in maintaining cellular integrity and the immune system. It is essential for the regulation of synthesis and degradation of nucleic acids, proteins, lipids and carbohydrates. With a varied diet, your body usually gets enough zinc. Food sources of zinc include chicken, red meat, and fortified breakfast cereals. The requirement for non-pregnant and non-lactating women is 2960µg/g, while it is 1390µg/g per day in the case of children aged 4-6 yr. Its deficiency causes retardation in growth associated with delayed sexual and bone maturation, colds, wound healing, diarrhea, loss of appetite and impaired immune function.

Vitamin A: Vitamin A is important for normal vision, the immune system, reproduction, maintenance of epithelial cell integrity, immune system and growth and development. Vitamin A also helps your heart, lungs, and other organs work properly. Carotenoids are pigments that give yellow, orange, and red fruits and vegetables their colour. The requirement of vitamin A for nonpregnant and non-lactating women is 500µg/g, while it is 275µg/g per day in the case of children aged 4-6 years. Night blindness is the hallmark of an early symptom of vitamin A deficiency and there is a chance of anaemia, diarrhoea, measles, malaria and respiratory infections are also enhanced.

Vitamin C: Vitamin C is essential for the growth and repair of tissues in all parts of your body such as skin, bone, teeth and cartilage. It helps the body make collagen, an important protein used to make skin, cartilage, tendons, ligaments, and blood vessels and increases iron absorption from the gastrointestinal tract. Vitamin C is needed for healing wounds, and for repairing and maintaining bones and teeth. The requirement of vitamin C for adult women is 60 mg per day, while it is 90 mg/day in adult men. The deficiency causes scurvy which is characterised by bleeding gums, bruising and poor wound healing in the teeth and is also associated with joint and muscle pains.



7.0 Anti-Nutritional Factors

Erucic acid: Erucic acid is one of the anti-nutrients for human health. It is a monounsaturated fatty acid that is found predominantly in mustard and rapeseed oil. Its large concentration in edible oil impairs myocardial conductance, causes lipidoses in children and also raises blood cholesterol. Less than 2% erucic acid is required for health.

Glucosinolates: Glucosinolates have different mechanisms and routes and it is largely related to anti-inflammatory and antioxidant mechanisms. It protects from cancer and is also able to kill the cancer cells. It produces glucose, sulfate and other aglucon products when broken down by myrosinase. Less than 33% glucosinolates is required for health.

Kunitz trypsin inhibitor (KTI):

Kunitz trypsin inhibitor is a non-glycosylated protein and harmfully alters trypsin interpreting it as unavailable to bind with proteins for the digestion process. It adversely affects human growth and leads to indigestion. It has an antinutritional effect on digestive activity and is considered an anti-nutritional factor.

Biofortified crop cultivars: Biofortified food crops like cereals, legumes, vegetables and fruits provide sufficient levels of micronutrients to vulnerable populations. Though a greater emphasis is being placed on transgenic research, the success rate and acceptability of breeding are much higher. India has significantly increased its food grain production from 50.82 million tons (1950-1951) to 332.22 million tons during 2023-24.

8.0 Biofortification in Vegetable Crops

The world produces enough food to feed all of its 8 billion people. But about 733 million people (1 in 11) go hungry every day in 2023. Whereas in Africa it is estimated highest (1 in 5 people) people faced hunger. About 13.7% of India's population was undernourished during 2021-13 (SOFI 2024). Nearly 2.8 billion people worldwide cannot afford a healthy diet (35% of the global population). More people in developing countries suffer from micronutrient malnutrition also known as "hidden hunger". Mainly, vulnerable people suffer a deficiency of micronutrients like iodine, iron, zinc, and vitamin A across the Globe. The vulnerable people cannot afford the diversified food. They only consumed a cereal-based diet with fewer pulses and vegetables. They occasionally consume fruits, nuts, and non-veg items. Largely pregnant women, lactating women and children are the most sufferers of the balanced dietary pattern. Current Govt support is not enough to meet the requirements of vulnerable people. The current



food chain does not have biofortified food, and availability is a bigger challenge for everyone. Hence, more biofortified crops and varieties are to be available at the market, input dealers, Govt seed supply agencies, or in the seed chain system. So, biofortified crop production needs to be sufficient, and its availability to people will be more for their consumption. Govt should take the initiative to provide biofortified crops of food under different schemes and PDS. The change in our current conventional approaches to improved agronomic practices, transgenic, and biotechnology for biofortified crop production. Biofortified foods are to be included in our dietary patterns for more vitamins and micronutrients for poor people. The biofortified crops are more nutrient-dense than non-biofortified crops. More supplementary efforts are required to revise the predominant genomes by employing molecular techniques that can open new pathways for biofortification.

Vegetables are one of the important sources of nutrients in the human food system and are known as 'protective foods' against various diseases. Minerals and vitamins constitute an integral component of human growth and development (Lal et al., 2020). The vitamins such as A, C, E, and beta-carotene are effective antioxidants that also help in improving health by employing other mechanisms (Parulekar, Haldankar, Dalvi, & Bhattacharyya, 2019). The crops like amaranths, ash gourds, cabbage, curry leaf, fenugreek, palak, bitter gourd, spinach, lettuce, okra, onion, radish, and pea contain a fair amount of Ca, Fe, I, K, P & Na (Gomathi, Vethamoni, & Gopinath, 2017; Singh, 2020; Singh, Selvakumar, Mangal, & Kalia, 2020).

Biofortification provides more nutrients through conventional plant breeding; parent lines with high vitamin or mineral levels can be crossed over several generations to produce plants that have the desired nutrients. Transgenic crops are plants that have been modified through genetic engineering techniques. These crops have had specific genes inserted into their DNA to give them new characteristics or traits that are not naturally found in the species through traditional breeding methods. Now more emphasis is given on transgenic crops like tomato, cassava, potato, beans, sweet potato and other vegetable crops. The details of biofortified vegetable crops are as follows:

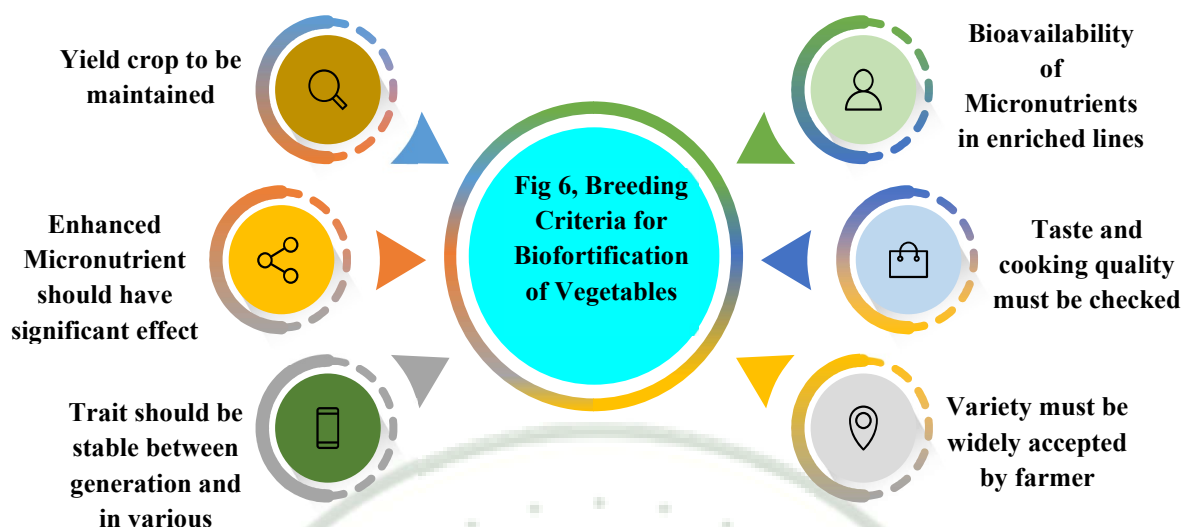


Table 2, Biofortification in Vegetable Crops

Crop	Biofortified element/mineral/vitamin
Potato	Protein, anthocyanin, amino acid, starch, carbohydrate (fructan)
Onion, Broccoli	Selenium
Lettuce, Beans	Iron
Carrot	Calcium
Radish	Selenium
Tomato	Stilbene, flavonoids, chlorogenic acid, anthocyanin folate, phytoen, lycopene β -carotene, provitamin A, Iodine, Zinc
Cassava	Protein, carotene and mineral contents Zn, Se, Cu, I
Sweet potato	Protein, Carotene
Broccoli	Selenium
<i>Brassica</i> spp.	Selenium, carotene
Spinach	Iodine
Cucumber	Potassium



Tomato

Tomato crops have developed as a promising strategy to combat global iron deficiency through agronomic biofortification with iron (Fe). Iron is essential for human health and plays a critical role in the growth and development of crops. Tomato is enriched with carotenoids (β -carotene), anthocyanins (lycopene) and vitamins C and E. Vitamins A, C and E, and the minerals copper, zinc and selenium are the nutrient antioxidants. Other dietary food compounds, such as the phytochemicals in plants, are believed to have greater antioxidant effects than vitamins or minerals. It works as an antioxidant to perform all metabolic activities. The average anthocyanin content of the transgenic fruit was 0.1 mg g⁻¹ fresh weight, which was 70-100-fold higher than that of the control fruits. Resulting in transgenic tomato lines produced an increase of up to 78-fold in fruit peel flavanols, mainly due to an accumulation of rutin (Muir *et al*, 2001).

Potato

Biofortified potatoes contain high levels of vitamin C. That helps with the absorption of iron and low levels of phytates, which inhibit the absorption of iron. Biofortified potatoes have the potential to make a substantial contribution to reducing micronutrient malnutrition across the World. These potatoes have starch, which is the primary storage component and have 70% tuber dry matter. After successfully improving the agronomic breeding of potatoes, the transgenic plant has been enriched with high starch content and all essential amino acids, particularly lysine, tyrosine, and sulfur amino acids. All this increases the protein content of the potato.

Cauliflower

Coloured cauliflowers like yellow, green and purple are more nutritionally valuable than white due to a higher concentration of vitamins and micronutrients. It looks so attractive. Biofortification enriches the vegetable crops most eaten by hundreds of millions of smallholder farmer families with higher levels of vitamin A, iron, and zinc. The use of the orgene to increase carotenoid content in cauliflower. Biofortified vegetables are mostly climate-smart varieties through conventional and agronomic breeding techniques. That helps to improve human nutrition and resilience to climatic hazards.

Cabbage



Cabbage is used for stomach pain, excess stomach acid, and stomach and intestinal ulcers. Red cabbage has higher levels of antioxidants than other types of cabbage. Cabbage is also used to treat asthma, morning sickness, etc. Red cabbage contains anthocyanins and presents high antioxidant properties. That helps human beings to decrease the risk of cancer, osteoporosis, heart disease, cardiovascular diseases and brain disorders.

Carrot

Red carrots are the richest source of Vitamin A, and it is essential for healthy eyes. Red carrots contain anthocyanin. Anthocyanin is a powerful antioxidant that can help prevent cell damage and decrease the risk of a heart attack. Orange carrots are loaded with vitamins A, E and K. Genetically engineered carrots are rich source of Calcium (Ca). Transgenically modified carrots expressed increased levels of the plant Ca transporter SCAX1 (Park *et al* 2003).

Pumpkin

The total carotenoid and β -carotene isomer contents increased according to the cooking methods applied, and the high contents of total carotenoids in pumpkin (Carvalho and Lara, 2014).

9.0 Conclusion

In the 21st century, hunger, malnutrition and climate change are the major challenges that can be overcome through enough nutrient-rich biofortified crops for long-term benefits. Our strategy should be environmentally viable, economically beneficial and nutritionally sustainable. Many health problems can be prevented and controlled by increasing awareness among people on biofortified crops with climate resilience. The most common and feasible approaches to biofortification are agronomic biofortification, conventional breeding and transgenic techniques. That ensures the nutritional quality of staple and vegetable crops. All policymakers, donor agencies, nutritionists, breeders, Govt. The Department, NGOs and social scientists initiate need-based programmes jointly to address the global issue of malnutrition and hunger. Biofortified crops nowadays play a crucial role in enhancing the quality of human nutrition. Many syndromes or chronic disorders that are caused by a deficiency of micronutrients can be eradicated. Especially, biofortified crops are beneficial to the rural population where health security is at risk. An intensive and combined effort of public-private partnership is required for mass on biofortified crops among the rural and urban people, from awareness programmes to the production of crops. First, we have to strengthen the seed chain



system. Timely availability of genetically pure quality biofortified seeds with different varieties to farmers for the production of crops. Extend all possible support to farmers for the seed village programme on biofortified crops. Grow more commercial production of biofortified crops across the World. Provide all input support and market support to farmers for better dissemination of technologies and varieties of crops as well as popularity among the farmers for large extension. From time to time, conduct more training, social research and developmental initiatives to popularize biofortified crop varieties.

REFERENCE

- Banuelos, G. S. *et al.* (2015) Irvin Arroyo, Ingrid J. Pickering, Soo In Yang, John L. Freeman. 2015. Selenium biofortification of broccoli and carrots are grown in soil amended with Se-enriched hyperaccumulator *Stanleya pinnata*. *Elsevier*, 166: 603–608.
- Bazuin, S. *et al.* (2011). *Biotechnol. Adv.*, 29:908–912.
- Bergougoux, V. (2014). *Biotechnol. Adv.* 32: 170-189.
- Borrill, P. *et al.* (2014) *Font. Plant Sci.* 5:53.
- Bouis, B. *et al.* (2011) *Suppl. Food Nutr. Bull.* 32 (1): 31-40.
- Cakmak, I. (2010) *J. Agric. Food Chem.* 58:9092–9102.
- Cakmak, I. (2009). *J. Trace Elem. Med. Biol.* 23:281–289.
- Carvalho, Lara de Azevedo Sarmet Moreira Smiderle (2014). *Food Sci. Technol.* 34(2): 365-370.
- Ducreux, L.J.M. *et al* (2005) *J.Exp. Bot.*, 56: 81-89.
- Food and Nutrition Board, 2013. Dietary Reference Intakes. Tables and Application.
- Gaj, T. *et al.* (2013). *Trends Biotechnol.* 31:397–405.
- Gao, C.Q. *et al* (2013). *Poult. Sci.* 92:2923–2929.
- Garza, R.I.D. *et al.* (2007). *Nat. Aca. Sci.* 107 (10): 4218-4222.
- Gill, J. *et al.* (2014) The shutdown of celiac disease-related gliadin epitopes in bread wheat by RNAi provides flours with increased stability and better tolerance to over-mixing. *PLoS One*. 9:e 91931.
- Grillet, L. *et al.* (2014). *Front. Plant Sci.* 4:535.



- Gupta, S. (2014). Commercialization of transgenic horticultural crop: challenges and future prospects. *Ann. Hort.* 7(2): 129-134.
- Hirschi, K.D. (2009). *Annu. Rev. Nutr.*, 29:401–421.
- James, C. 2013. Global status of commercialized biotech/GM crops: 2013. The international service for the acquisition of agri-biotech applications (ISAAA), summary available at <http://www.isaaa.org/>.
- Jeong, *et al.* (2008) *J. Proc. Natl. Acad. Sci.* 105:1777–1778.
- Kalpana, P. *et al* (2014). *Int. J. Res. Appl. Nat. Social Sci.* 2(3): 103-110.
- Kershen, D.L. (2010). *New Biotechnol.*, 27:623–627.
- Kiran, Aysha, Abdul Wakeel, Khalid Mahmood, Rafia Mubaraka, Hafsa, and Stephan M. Haefele. "Biofortification of staple crops to alleviate human malnutrition: contributions and potential in developing countries." *Agronomy* 12, no. 2 (2022): 452. Lukaszewicz, M. *et al.* (2004) *J. Agric. Food Chem.* 52 (6):1526–1533.
- Maligeppagol, M. *et al.* (2013) *Curr Sci.* 105: 72-80.
- Martina, L. *et al.* (2011) *J. Plant Nutr. Soil Sci.* 174: 480–486.
- McLean, E. *et al.* (2009) *Public. Health. Nutr.* 12: 444–54.
- Mugode, L. (2014) *J. Agric. Food Chem.* 62:6317–6325.
- Muir Shelagh, R. *et al.* (2001). *Nat. biotechnol.* 19:470-474.
- Nassar, N.M.A. *et al.* (2009) *Recent Patents Food, Nutr. Agri.*, 1: 32-38.
- Neste, I P. *et al* (2006) *J. Nutr.* 136 (4): 1064-1067.
- Nestel, P. J. (2006). *JNutr.* 136:1064–1067.
- Park M.K. *et al.* (2003) *J. food sci.* 68(4):1248-1253.
- Prasad B.V.G. *et al* (2015) *J. Agric. Eng. Food Tech.* 2350-0263: 95-99.
- Puchta, *et al.* (2013). *Int. J. Dev. Biol.* 57:629–637.
- Seppanen Mervi M. *et al* (2010) *Pl. Soil* 337:273–283.



ISSN:3107-4200

SABUJEEMA
Agri Newsletter

An International Newsletter for Agriculture and Allied Sciences



Shamah, Teresa, and Salvador Villalpando. "The role of enriched foods in infant and child nutrition." *British Journal of Nutrition* 96, no. S1 (2006): S73-S77.

Tang, G. *et al.* (2009). *Am. J. Clin. Nutr.* 89:1776–1783.

Tanumihardjo, S.A. *et al.* (2010). *JNutr. Res.* 80:336–350.

Verhoeven, A. *et al.* (2002) *J. Exp. Bot.* 53: 377-383.

White, P.J. and Martin R. Broadley (2009). *New Phytol.* 182: 49–84.



Volume 3 - Issue 02 (Mar-May)-2026



Efficient Water Management and Integrated Farming Practices Enhanced Farm Profitability of Sri B. Basker Reddy

Dr. P. Archana¹, Dr. K. Kalyani²

¹Coordinator, TRVK, Mahabubnagar

²Scientist (CP), TRVK, Mahabubnagar



Sri B. Basker Reddy, a progressive farmer from Dokur village of Deverakadra mandal in Mahabubnagar district, has emerged as a successful farmer through the adoption of improved water management technologies and sustainable integrated farming practices. Born on 8th October 1959 at Dokur village, he belongs to the OC community and completed his education up to 10th class. With nearly eight years of farming experience, he transformed his agricultural activities into a profitable and environmentally sustainable farming system through innovation, hard work and scientific management practices.

Sri Basker Reddy owns 10 acres of irrigated red soil land, where bore well irrigation is the primary source of water. Realizing the increasing scarcity of water resources and rising cultivation costs, he adopted drip irrigation technology for efficient water utilization. The drip irrigation system ensured timely and uniform moisture supply to crops, minimized water wastage and improved overall crop productivity. This technology proved highly beneficial under the dryland conditions prevailing in Mahabubnagar district.

The farmer follows a diversified and integrated cropping system consisting of Banana, Ginger, Turmeric, Garlic and vegetables like Brinjal and Beans. During the Kharif season, he cultivates Banana + Ginger + Turmeric as an integrated cropping system, while Garlic is grown during the Rabi season. This diversified cropping pattern enabled efficient utilization of land, labour and water resources throughout the year while reducing the risks associated with monocropping.



In addition to drip irrigation, Sri Basker Reddy adopted several eco-friendly and organic farming practices for improving soil fertility, moisture conservation and crop health. He regularly applies Panchagavya, Jeevamrutham, oil formulations and oil cakes prepared from Groundnut, Safflower, Neem and Mahua. He also uses bio-agents such as Trichoderma and Pseudomonas for disease management and enhancement of beneficial soil microorganisms. Farmyard manure, poultry manure and bio-inputs are extensively utilized in his fields to improve soil organic matter and maintain long-term soil health.

The combined adoption of drip irrigation and organic nutrient management significantly improved crop growth, root development and moisture retention capacity of the soil. The farmer observed reduced weed growth, efficient fertilizer utilization and lower incidence of pests and diseases. These practices considerably reduced dependency on chemical fertilizers and pesticides, thereby lowering cultivation costs and enhancing sustainability.

Crop wise improved water management technologies adopted, saving of water, cost of cultivation, gross returns, net returns per acre

Crop	Improved water management technologies adopted	Saving in water	Yield (Kg/acre)	Cost of cultivation (Rs/acre)	Gross Returns (Rs/acre)	Net returns (Rs/acre)
Banana+Turmeric+ Ginger	Drip irrigation		Banana: 500 plants-each plant -10 dozens 5000 dozens (each dozen sold 50 Rs/). Turmeric: 1q/acre Ginger: 3 q/acre	1,00,000	2,50,000 40,000 30,000 3,20,000	2,20,000
Garlic	Drip irrigation		2 q/acres	30,000	40,000	10,000

Under the Banana + Turmeric + Ginger cropping system, drip irrigation played a crucial role in efficient water management and higher productivity. In Banana cultivation, about 500 plants were maintained per acre and each plant yielded nearly 10 dozens of bananas, resulting



in approximately 5000 dozens per acre. Each dozen was sold at Rs.50. Turmeric yielded about 1 quintal per acre, while Ginger yielded around 3 quintals per acre. The total cost of cultivation for the integrated cropping system was nearly Rs.1,00,000 per acre. The farmer realized gross returns of around Rs.3, 20,000 per acre and net returns of about Rs.2,20,000 per acre, demonstrating the profitability of improved water management practices.

During the Rabi season, Garlic was cultivated under drip irrigation, which helped maintain optimum soil moisture and improve bulb development. The crop yielded about 2 quintals per acre. The cost of cultivation was around Rs.30,000 per acre and the farmer realized gross returns of approximately Rs.40, 000 per acre with net returns of Rs.10,000 per acre. Significant water saving was observed compared to conventional irrigation methods, especially during periods of water scarcity.

The remarkable success achieved by Sri B. Basker Reddy created a strong spread effect among farmers in Dokur village and nearby areas. Many farmers visited his fields to observe the drip irrigation system and integrated nutrient management practices. Motivated by his success, several farmers in the region started adopting drip irrigation, organic formulations and bio-input-based farming practices for efficient water management and sustainable agriculture.

Sri B. Basker Reddy stands as a model farmer in Mahabubnagar district for his successful adoption of improved water management technologies and integrated farming systems. His innovative approach, scientific resource management and commitment towards sustainable agriculture significantly enhanced farm productivity, profitability and environmental sustainability, serving as an inspiration to farming communities in the district.





Article ID: SAN/03-02/22

Success Story

From Tradition to Transformation: The Inspiring Success Story of Progressive Woman Farmer Smt. Eshavoni Janamma

Dr. P. Archana¹, Dr. K. Kalyani²¹Coordinator, TRVK, Mahabubnagar²Scientist (CP), TRVK, Mahabubnagar

Smt. Eshavoni Janamma is a successful and progressive woman farmer from Koukuntla Village and Mandal of Mahabubnagar District. Born in the year 1978, she belongs to the BC community and is presently 48 years old. Despite having formal education only up to the 8th class, she has emerged as an inspiring example of how determination, innovation and scientific farming practices can transform agriculture into a profitable enterprise. With nearly 15 years of farming experience, she successfully established herself as a role model for women farmers in the region.

Mrs. Janamma owns a total of 18 acres of irrigated land with Alfisol soils, which are suitable for cultivation of horticultural and commercial crops. Her entire farming system depends on borewell irrigation, and she efficiently utilizes available water resources through modern irrigation practices such as drip irrigation and mulching. Unlike traditional mono-cropping systems, she adopted a diversified farming model by cultivating high-value crops such as Cotton, Dragon Fruit, Tomato, Lime, Watermelon, Papaya and Brinjal. This diversification helped her reduce risk, improve income stability and enhance resource utilization throughout the year.

One of the major strengths of Smt. Janamma is her willingness to adopt innovative and sustainable agricultural technologies. She practices organic and natural farming methods, focusing on maintaining soil health and reducing dependency on excessive chemical inputs. She adopted drip irrigation in crops like cotton, papaya and lime, which significantly reduced water wastage while improving crop productivity. In crops like lime and watermelon, she also



practiced mulching, which conserved soil moisture, controlled weeds and improved fruit quality. In brinjal cultivation, she utilized crop residue mulching, which enhanced soil organic matter and reduced evaporation losses.

Smt. Janamma has also shown remarkable interest in cultivation of high-value horticultural crops. She established a Dragon Fruit orchard using the variety Shiami Red along with tomato (Saho variety) as an intercrop during the initial years. She adopted the pendal system for dragon fruit cultivation, which provided proper support for plant growth and improved fruit yield. This innovative cultivation method not only increased profitability but also demonstrated the potential of exotic fruit cultivation under local conditions. Her success in dragon fruit cultivation attracted the attention of neighboring farmers and motivated many of them to diversify towards horticultural crops.

The economic performance of her farm clearly reflects the success of scientific crop management practices. In cotton cultivated under drip irrigation, she achieved a productivity of 14.5 quintals kapas per acre, obtaining a gross return of Rs. 1,02,000 and a net return of Rs. 54,000 per acre. Her dragon fruit orchard produced about 8,500 kg per acre, generating a gross return of Rs. 4,25,000 and a net return of Rs. 2,45,000 per acre, proving it to be one of the most profitable enterprises on her farm.

Similarly, in lime cultivation with drip irrigation and mulching, she harvested around 7,200 kg per acre with a net income of Rs. 1,25,000 per acre. In watermelon cultivation, adoption of drip irrigation and mulching resulted in a productivity of 18,000 kg per acre, generating net returns of about Rs. 1,25,000 per acre. Her papaya crop (Taiwan Red Lady variety) yielded around 24,000 kg per acre and provided a net income of nearly Rs. 1,90,000 per acre. In brinjal cultivation, the use of drip irrigation and crop residue mulching resulted in a yield of 16,500 kg per acre with net returns of Rs. 1,45,000 per acre. The benefit-cost ratios obtained in different crops clearly indicate the profitability and sustainability of her farming system.

Through efficient crop planning and adoption of improved management practices, Smt. Janamma transformed her farm into a successful horticultural production unit. Her farming approach emphasizes water-use efficiency, crop diversification, soil health management and sustainable income generation. She effectively demonstrated that scientific farming combined with hard work can generate substantial income even under semi-arid conditions.



Apart from achieving economic success, Smt. Janamma also created a strong spread effect among fellow farmers, particularly women farmers in and around Koukuntla village. Many farmers visit her fields to observe modern cultivation techniques such as drip irrigation, mulching, dragon fruit cultivation and integrated crop management practices. Her success inspired neighboring farmers to adopt horticultural crops and water-saving technologies for improving farm profitability.

Smt. Eshavoni Janamma stands as a shining example of women empowerment in agriculture. Her dedication, innovative mindset and commitment towards sustainable agriculture transformed her into a progressive farmer and an inspiration to the farming community. Through her achievements, she proved that women farmers can successfully lead profitable and sustainable agricultural enterprises while contributing significantly to rural development and livelihood improvement.



