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IoT-ENABLED SENSOR-BASED IRRIGATION

IMPROVING WATER USE EFFICIENCY IN AGRICULTURE

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FROM THE FOUNDER & CEO'S DESK

Dear Readers,

Welcome to the latest issue of Just Agriculture—a publication dedicated to empowering, informing and inspiring the agricultural community. The landscape of agriculture continues to evolve, we are witnessing significant advancements in technology, sustainability practices, and global trends that are reshaping the way we produce, consume, and think about food, from precision farming to the integration of AI in crop management, innovation is at the heart of the agricultural revolution.

However, alongside these opportunities, challenges like climate change, supply chain disruptions and labor shortages remain pressing concerns that require our collective action and resilience.

At Just Agriculture, we are committed to being a bridge between these emerging technologies and the farmers, agribusinesses and stakeholders who will shape the future of agriculture. In this issue, we delve into topics that matter most: sustainable farming practices, the rise of agri-tech and the crucial role of policy in ensuring a thriving agricultural ecosystem. We also highlight success stories from across the globe, demonstrating how

adaptability and innovation are driving positive change.

I believe that the future of agriculture is bright, but it requires all of us—farmers, scientists, policymakers and consumers—to work together toward a common goal: ensuring food security, environmental sustainability and the well-being of future generations.

Thank you for your continued support and for being a part of this incredible journey. I hope this issue inspires you as much as it has inspired us to bring it to you.

Dr. D.P.S. BADWAL
Founder & CEO,
Just Agriculture-the Magazine

Publisher & Editor:
Dr. D.P.S. Badwal on behalf of Just Agriculture Communications Group & printed at Just Agriculture Publications, Jalandhar.

FROM THE
CHIEF EDITOR'S DESK

Dear Readers,

The journey of agriculture is a story of resilience, innovation, and enduring hope. As we present this issue of Just Agriculture, we reaffirm our commitment to strengthening the backbone of our nation—our farmers, researchers, and agricultural entrepreneurs. This edition brings forward timely insights on key themes shaping Indian agriculture, where science, sustainability, and innovation converge.

We begin with The Carbon Balance: Synchronizing Agronomic Strategy with Soil Carbon Sequestration, highlighting the importance of carbon management in modern farming systems. Continuing our focus on sustainable resource use, The Dawn of Steam-Powered Agriculture: A High-Tech Solution to Extreme Water Scarcity explores innovative technologies designed to address one of agriculture's most pressing challenges—water scarcity.

The issue also highlights opportunities for rural prosperity through Integrated Goat Farming: A Sustainable Approach for Enhancing Farmers' Income with Low Investment, demonstrating how livestock-based enterprises can strengthen farm livelihoods. On the scientific front, Acorus calamus: A Promising Medicinal Herb with Diverse Therapeutic Applications sheds light on the immense potential of medicinal plants in agriculture and healthcare.

Furthering our commitment to technological advancement, we present IoT-Enabled Sensor-Based Irrigation: Improving Water Use Efficiency in Agriculture, showcasing how smart technologies are transforming irrigation practices and promoting sustainable water management. We also feature Clean Milk Production: A Public Health Significance, emphasizing the critical role of quality milk production in ensuring food safety and public health.

At Just Agriculture, we remain committed to providing a credible platform for knowledge exchange that translates into meaningful action. I extend my gratitude to our authors, reviewers, editorial team, and above all, the farming community whose dedication inspires our work.

Let us continue sowing innovation and cultivating sustainable growth.

Dr. Sushila Hooda
Chief Editor,
Just Agriculture-The Magazine

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THE CARBON BALANCE:
SYNCHRONIZING AGRONOMIC STRATEGY WITH SOIL CARBON SEQUESTRATION

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INTRODUCTION

Agriculture is both a source and a sink of atmospheric carbon, playing a critical role in global climate dynamics. Continuous cultivation, intensive tillage and inadequate nutrient management have led to depletion of soil organic carbon (SOC) particularly in developing countries. At the same time, soils possess immense potential to sequester carbon through improved agronomic practices. The concept of carbon balance refers to the relationship between carbon inputs such as crop residues, root biomass and organic amendments and carbon outputs including soil respiration, erosion and management induced losses. When inputs exceed outputs, soils act as carbon sinks otherwise they become carbon sources. Synchronizing agronomic strategies with soil carbon sequestration is essential for enhancing soil fertility, improving resource use efficiency and ensuring long term sustainability under changing climatic conditions.

SOIL CARBON SEQUESTRATION: MECHANISMS AND IMPORTANCE

Soil carbon sequestration involves the capture of atmospheric carbon dioxide through plant photosynthesis and its storage in soil as organic matter. Soil organic carbon exists in different fractions such as active, slow and passive pools, each varying in stability and turnover rate. Soil microbial communities play a key role in carbon stabilization through decomposition, humification and aggregate formation. Agronomic practices that enhance microbial diversity and activity indirectly improve long-term SOC stabilization.

Increased SOC contributes to:

- Improved soil structure and aggregation
- Enhanced water-holding capacity
- Greater nutrient availability
- Increased microbial activity

Studies indicate that even a 0.1% increase in SOC can significantly improve soil productivity and resilience making it a critical indicator of soil health.

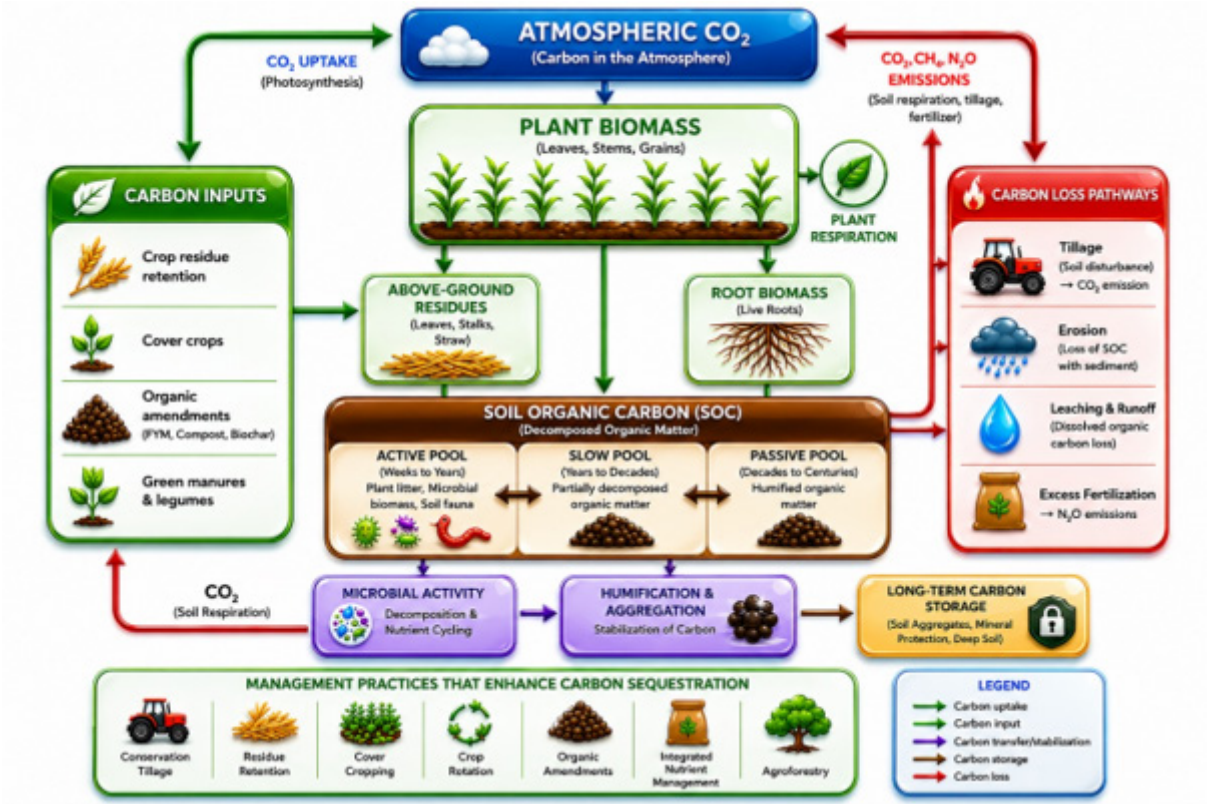

Figure: Carbon cycle in agroecosystems illustrating carbon inputs through photosynthesis and residues transformation into soil organic carbon pools and losses through respiration, erosion and management practices.

Soil acts as a carbon sink when inputs from plant biomass and organic amendments exceed losses through respiration and disturbance.

Agronomic strategies for enhancing carbon balance

- **Conservation tillage**

Reduced or zero tillage minimizes soil disturbance thereby reducing carbon oxidation and CO_2 emissions. It promotes residue retention and enhances soil aggregation leading to greater carbon stabilization.

- **Crop residue management**

Returning crop residues to the soil increases carbon inputs and improves microbial activity. Residue retention has been shown to increase SOC levels and reduce soil erosion.

- **Diversified cropping systems**

Crop rotations, intercropping and inclusion of legumes enhance biomass production and carbon inputs. Deep rooted crops contribute to subsoil carbon storage improving long term sequestration.

- **Integrated nutrient management (INM)**

The combined use of organic and inorganic fertilizers improves soil organic matter and microbial activity. Organic inputs such as farmyard manure and compost are particularly effective in increasing SOC.

Figure: Components of INM

COVER CROPPING

Cover crops protect soil from erosion, enhance biomass input and improve carbon retention. They also improve nitrogen cycling and reduce nutrient losses.

Carbon loss pathways and mitigation

Carbon balance can be expressed as:

Carbon Balance = Carbon Inputs - Carbon Outputs

- Inputs: Crop residues, root biomass, organic amendments
- Outputs: Soil respiration, erosion, tillage losses, residue burning

A positive carbon balance results in carbon sequestration while a negative balance leads to soil degradation and increased atmospheric CO_2. Adopting conservation agriculture practices significantly reduces these losses. For example, no-till systems can reduce CO_2 emissions by up to 30% compared to conventional tillage.

Linking carbon sequestration with climate resilience

Soils rich in organic carbon are more resilient to drought and extreme weather conditions. Higher SOC improves water retention and nutrient buffering capacity, enabling crops to withstand stress. Moreover, soil carbon sequestration contributes to climate change mitigation by removing CO_2 from the atmosphere, aligning agriculture with global sustainability goals.

India-specific perspective on soil carbon sequestration

India's agricultural soils are generally low in soil organic carbon (SOC), in many cultivated Indian soils generally ranges between 0.3 and 0.6%, particularly in arid and semi-arid agroecosystems. This presents a substantial opportunity for enhancing soil carbon through improved agronomic management.

Emerging approaches and technologies

Recent advancements are enhancing carbon sequestration potential:

- Precision agriculture for optimized input use
- Remote sensing for SOC monitoring
- Biochar application for long-term carbon storage
- Carbon credit systems incentivizing farmers

These innovations are helping bridge the gap between productivity and sustainability (Paustian et al., 2019).

Policy Support, challenges and future directions

In recent years, India has increasingly recognized the importance of soil carbon management in achieving sustainable agriculture and climate resilience. Government initiatives such as the National Mission for Sustainable Agriculture (NMSA) and the Soil Health Card Scheme have encouraged farmers to adopt balanced fertilization, organic nutrient sources and conservation-based farming practices. These programs aim not only to improve soil fertility and productivity but also to enhance soil organic carbon stocks which are essential for long term soil sustainability.

Despite the growing awareness of soil carbon sequestration its practical implementation still faces several challenges. Soil carbon behavior differs widely across regions due to variations in soil type, climate, cropping systems and management practices. As a result, a practice that performs well in one region may not produce similar results elsewhere. Another major challenge is the difficulty in accurately measuring and monitoring changes in soil organic carbon over time, as these changes often occur slowly and require long term assessment.

Farmer adoption also remains a concern, particularly in developing regions where

limited resources, lack of technical knowledge and economic uncertainties discourage the adoption of improved practices. In many cases, immediate economic returns are prioritized over long term environmental benefits.

Looking ahead, future research should focus on developing region specific and crop specific carbon management strategies that are practical and economically feasible for farmers. Advanced technologies such as remote sensing, precision agriculture, artificial intelligence and digital soil monitoring tools can play an important role in improving the assessment and management of soil carbon. Long term field studies are also needed to better understand carbon dynamics under different farming systems. Strengthening policy support, increasing farmer awareness and promoting incentive-based programs will be essential for encouraging wider adoption of carbon smart agricultural practices and ensuring sustainable soil management in the future.

CONCLUSION

The integration of agronomic strategies with soil carbon sequestration offers a practical pathway to address the dual challenges of climate change and agricultural sustainability. Practices such as conservation tillage, residue management, diversified cropping systems and integrated nutrient management play a crucial role in maintaining carbon balance while enhancing soil health and productivity. In the Indian context, where soils are generally low in organic carbon, the adoption of integrated and carbon smart practices can significantly improve soil quality and resilience. Enhancing soil carbon stocks by 0.5-1.0 t C ha^{-1} yr^{-1} through integrated agronomic practices can substantially contribute to climate resilience, improved water and nutrient use efficiency and sustainable crop productivity. Thus, synchronizing water, nutrient and carbon management is essential for developing climate resilient agricultural systems and ensuring long term food and environmental security.

THE DAWN OF STEAM-POWERED AGRICULTURE:

A HIGH-TECH SOLUTION TO EXTREME WATER SCARCITY

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INTRODUCTION

Agriculture across the world is entering a new era of uncertainty due to climate change, erratic rainfall, prolonged droughts, depletion of groundwater resources, and increasing desertification. Water scarcity has emerged as one of the greatest threats to sustainable crop production, particularly in rainfed and drought-prone regions. In India, especially in semi-arid areas like Marathwada, farmers frequently experience crop failures due to insufficient rainfall, high evaporation losses, degraded soils, and declining irrigation resources. Traditional irrigation systems are becoming increasingly inefficient under these harsh environmental conditions. One such pioneering concept, visualized in this cutting-edge graphic, is mobile subsurface steam generation and integrated drip irrigation – a futuristic approach that promises to secure food production even in the face of extreme water scarcity. To address these emerging challenges, innovative and futuristic technologies are required to ensure food security while conserving natural resources. One such advanced concept is the Mobile Subsurface Steam Generation and Integrated Drip Irrigation System, a high-tech agricultural innovation conceptualized by Krishi Vigyan Kendra, Hingoli. This integrated approach combines renewable energy, soil pasteurization, precision irrigation, and subsurface resource management to create a sustainable farming solution for drought-affected regions. This integrated system, designed specifically for challenging environments like the cracked-earth, dry spell conditions of a kharif soybean field, fundamentally reimagines how we manage soil health and water delivery. It moves away from broad-acre water application, focusing instead on hyper-efficient, targeted resource management below the soil surface.

STEPS OF STEAM-POWERED AGRICULTURE

Step 1: Mobile Steam Generation- The Clean-Energy Core

The process begins with a powerful, modular system mounted on a tracked vehicle for mobility across rugged terrain. This isn't just any farm machine; it's a self-contained energy and water processing unit.

Renewable Energy Powerhouse: Large solar panels capture abundant sunlight, powering the unit and reducing reliance on fossil fuels. This makes the entire operation sustainable and adaptable to remote locations without access to a power grid.

On-Site Water Purification: Water is sourced (potentially from marginal or brackish sources) and fed into an integrated purification system. This water is then heated in a superheated steam boiler, reaching temperatures of 200°C.

The Power of Pasteurization: This dry, superheated steam is the system's primary tool. Its high temperature doesn't just water the crops; it effectively sterilizes the soil, eliminating devastating nematodes, soil-borne fungi, and weed seeds that would normally rob plants of nutrients and water. This reduces the need for harsh chemical pesticides and herbicides, leading to a healthier ecosystem.

Step 2: Controlled Cooling & Precision Injection – Managing the Heat

Delivering 200°C steam directly to the soil would destroy beneficial microbial life and damage plant roots. The brilliance of this system lies in its precise control and cooling mechanisms.

Integrated Flash Cooling: As the high-pressure steam travels down the injection tines, it passes through a specialized flash cooler. This unit uses outside air or a fine water mist to rapidly lower the steam's temperature to a precise "Pasteurization Zone" target: 70-80°C.

Subsurface Application: This cooled, yet still highly effective, steam is injected via a specialized subsurface plough. This places the pasteurization treatment exactly where it's needed - approximately 30cm deep - focusing its energy on the root zone and minimizing resource loss to the atmosphere.

Step 3: A One-Two Punch: Subsurface Pasteurization and Drip Irrigation

The final phase combines the immediate benefits of pasteurization with the long-term efficiency of precision water delivery.

Optimizing the Root Zone: As the 70-80°C steam radiates through the target zone, it creates a sanitized, pest-free environment. This "Pasteurization Zone" ensures that the crop, in this case, drought-resistant soybeans, can establish a healthy and robust root system without competition or disease pressure.

The Next Level of Water Efficiency: Critically, this system doesn't rely solely on steam. Parallel to the steam lines, an integrated subsurface drip system is installed, complete with its own subsurface manifolds and drip lines. These lines can deliver micro-doses of water and essential nutrients directly to the plant roots, achieving water-use efficiency of over 95%.

Synergy for Success: By sterilizing the soil *before* water is applied, the drip system becomes immensely more effective. The crop has exclusive access to the water provided, without thirsty weeds or energy-sapping soil pathogens competing for the resource.

ENVIRONMENTAL AND SUSTAINABILITY BENEFITS

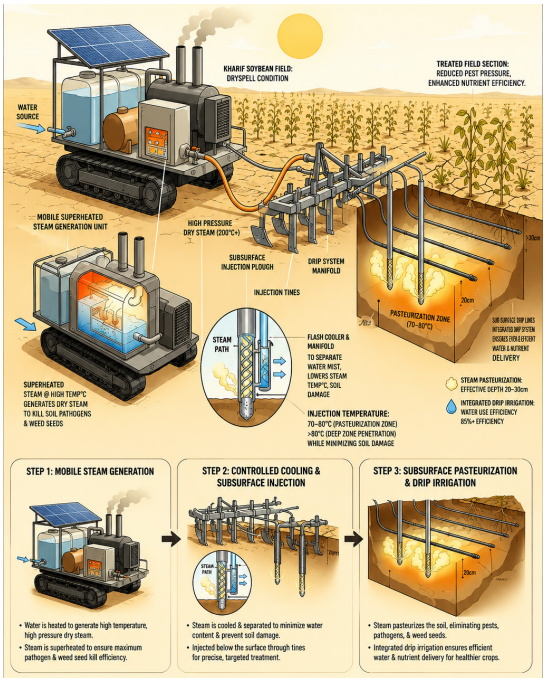
The proposed technology aligns closely with the principles of sustainable agriculture and climate-smart farming.

Key Environmental Benefits

- **Reduced Water Consumption:** Extremely high irrigation efficiency conserves scarce water resources.
- **Lower Chemical Usage:** Reduced dependency on pesticides and herbicides minimizes environmental contamination.
- **Reduced Carbon Footprint:** Solar-powered operation decreases fossil fuel consumption and greenhouse gas emissions.
- **Improved Soil Health:** Targeted treatment preserves long-term soil productivity and structure.
- **Climate Resilience:** The system enables crop production under extreme drought conditions.

A GLIMPSE INTO THE FUTURE OF FARMING

This visionary approach offers a compelling solution to the extreme water scarcity situations that are becoming increasingly common. The field section treated with this system clearly demonstrates the difference: reduced pest pressure, stronger crops, and, crucially, enhanced water use efficiency. While still a complex and futuristic concept, the mobile subsurface steam system embodies the kind of radical, integrated innovation required to sustain global agriculture in a changing climate. It is not just about adapting to a world with less water; it is about reinventing agriculture to be cleaner, more resilient, and ultimately, more productive in the very environments where we need it most. This technology doesn't just manage scarcity; it empowers us to cultivate abundance. This model conceptualized by KVK, Hingoli.



FUTURE PROSPECTS

The future scope of steam-powered agriculture is immense. With continued research and refinement, this technology could evolve into:

- Autonomous robotic field units
- Precision climate-resilient farming modules
- Smart irrigation networks integrated with IoT sensors
- Fully renewable-energy-powered farming ecosystems

Such systems may become essential for ensuring food security in water-stressed regions worldwide.

CONCLUSION

- The mobile subsurface steam generation and integrated drip irrigation system conceptualized by KVK, Hingoli represent a visionary and futuristic approach to climate-resilient agriculture. In an era marked by severe water scarcity, rising temperatures, and declining soil health, conventional farming practices alone may not be sufficient to sustain agricultural productivity.
- This innovative concept combines renewable solar energy, soil pasteurization, precision subsurface irrigation, and advanced resource management into a single integrated system. By sterilizing the soil using controlled-temperature steam and simultaneously delivering water and nutrients directly to the root zone, the technology maximizes water-use efficiency while minimizing pest pressure, weed competition, and chemical dependency.
- The system offers significant potential for dry land and drought-prone regions, particularly for crops like soybean cultivated under rainfed conditions. Although currently conceptual and experimental in nature, the model highlights the type of radical innovation required for the future of sustainable agriculture.
- The proposed technology is not merely a method of coping with water scarcity; it represents a transformational shift toward smarter, cleaner, and more resilient farming systems capable of ensuring food security under changing climatic conditions. With further research, pilot testing, engineering refinement, and institutional support, steam-powered precision agriculture could become an important component of next-generation climate-smart farming practices.
- Ultimately, this concept demonstrates that even under extreme environmental stress, scientific innovation has the power to transform scarcity into agricultural sustainability and productivity.

INTEGRATED GOAT FARMING:

A SUSTAINABLE APPROACH FOR ENHANCING FARMERS' INCOME WITH LOW INVESTMENT

Dr. Sandhya Morwal

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INTRODUCTION

Agriculture remains the backbone of the Indian economy, particularly for small and marginal farmers who depend on it for their livelihood. However, increasing input costs and uncertain climatic conditions have made conventional farming less profitable. In this context, integrated farming systems have gained importance as they provide a holistic approach to farming by combining multiple enterprises. Among these, integrated goat farming has emerged as a highly promising model due to its low investment requirement, adaptability, and multiple income-generating opportunities. Goats are often referred to as the "poor man's cow" because of their ability to thrive under resource-limited conditions and provide meat, milk, and manure.

PRINCIPLE OF INTEGRATED GOAT FARMING

The core principle of integrated goat farming is efficient resource utilization through recycling of waste materials. The concept of "waste to wealth" ensures that the by-products of one farming component are effectively utilized by another, thereby minimizing waste and maximizing output. For example, goat manure can be used as organic fertilizer for crops or as a nutrient source in fish ponds. Similarly, crop residues can be used as fodder for goats. This cyclic use of resources improves farm efficiency and sustainability.

COMPONENTS OF INTEGRATED GOAT FARMING SYSTEM

3.1 Goat and Crop Integration

Integration of goat farming with crop production allows farmers to grow their own fodder and utilize goat manure to enhance soil fertility. This reduces dependency on external inputs such as chemical fertilizers and commercial feed, ultimately lowering production costs.

3.2 Goat and Poultry Integration

Poultry farming can be effectively integrated with goat farming to generate additional income through eggs and meat. Poultry litter can be used as manure, improving soil quality and supporting crop growth. Proper management ensures efficient utilization of space and resources.

3.3 Goat–Fish Integration

The integration of goat farming with fish culture is an innovative approach. Controlled application of goat manure in fish ponds enriches water with essential nutrients such as nitrogen and phosphorus, promoting plankton growth. These plankton act as natural feed for fish, reducing the need for artificial feed. However, careful management is necessary to maintain water quality and prevent adverse effects due to over-fertilization.

3.4 Vermicomposting

Goat manure can be utilized for vermicomposting to produce high-quality organic fertilizer. With increasing demand for organic farming, vermicompost has gained significant market value. This not only improves soil health but also provides an additional source of income.

HIGHLIGHTS

- Shifted from traditional farming to a diversified, high-value horticulture system
- Adopted ODC drumstick cultivation (5 acres) with spacing (13 ft × 7 ft)
- Achieved early and consistent yield within 5–6 months
- Implemented climate-smart practices: mulching, bio-inputs, and drainage management
- Transitioned to a sustainable and market-oriented farming model.

BREED SELECTION AND FEEDING MANAGEMENT

Selection of suitable breeds is crucial for the success of goat farming. Indigenous breeds such as Sirohi, Jamunapari, and Barbari are well adapted to local climatic conditions and require minimal management. These breeds have good disease resistance, reducing veterinary expenses. Feeding management can be optimized by cultivating green fodder on-farm, thereby reducing dependence on costly commercial feed.

HOUSING AND MANAGEMENT PRACTICES

Low-cost housing can be constructed using locally available materials such as bamboo, wood, and tin. The housing structure should be well-ventilated, clean, and dry to prevent disease occurrence. Proper sanitation and regular cleaning are essential for maintaining animal health and productivity.

HEALTH MANAGEMENT

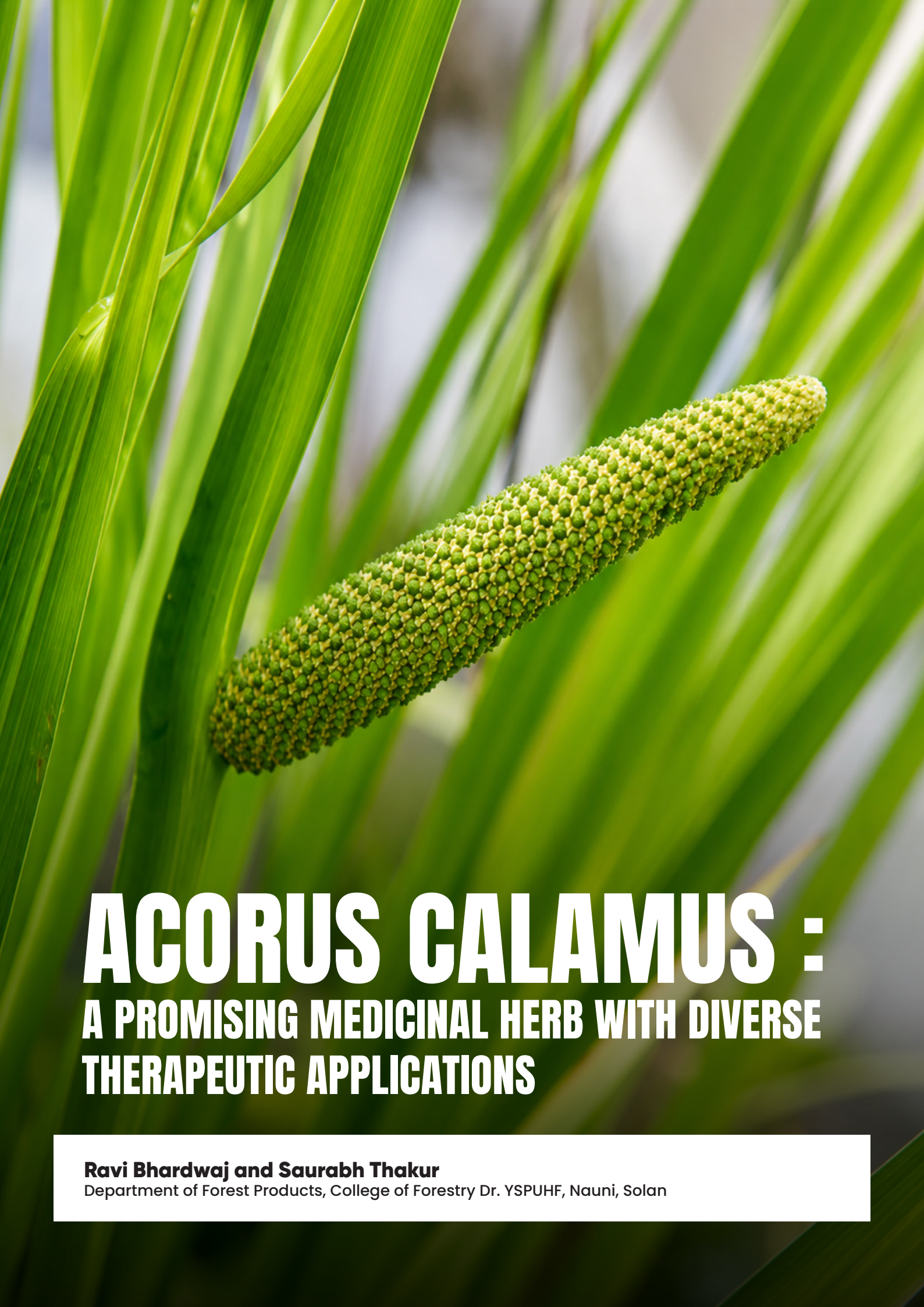
Effective health management includes regular vaccination, deworming, and provision of balanced nutrition. Early diagnosis and timely treatment of diseases are critical to minimizing losses. Healthy animals contribute to better growth, reproduction, and productivity.

ECONOMIC BENEFITS

Integrated goat farming offers multiple income streams, including the sale of goat kids, meat, milk, vermicompost, eggs, and fish. This diversification reduces financial risk and ensures a steady income. Farmers can achieve higher profitability with relatively low investment, making it suitable for small-scale farming systems. If a farmer starts this system with 10–20 goats, proper management can lead to an increase in herd size as well as income within 1–2 years. Thus, this model serves as a powerful means for small farmers to achieve self-reliance. However, successful implementation requires adequate market knowledge, proper planning, and timely training.

CONCLUSION

In conclusion, integrated goat farming can be considered an excellent model that ensures low investment, higher income, and efficient utilization of resources. It not only helps in enhancing farmers' income but also plays a significant role in environmental conservation and sustainable agricultural development. In the present scenario, where the cost of farming is continuously increasing, such models provide a new direction for farmers and contribute to their economic empowerment.



ACORUS CALAMUS : A PROMISING MEDICINAL HERB WITH DIVERSE THERAPEUTIC APPLICATIONS

Ravi Bhardwaj and Saurabh Thakur
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Plants have been utilized for medicinal and therapeutic purposes since ancient times. Their use has been documented in classical Unani texts, Egyptian papyri, and traditional Chinese writings. The Rig Veda contains some of the earliest references to the therapeutic benefits of medicinal herbs, while the Charaka Samhita and Sushruta Samhita provide detailed accounts of numerous healing plants. Herbal remedies have been employed for over 4,000 years by Unani Hakims, Indian Vaids, and various European and Mediterranean cultures.

According to the World Health Organization (WHO), approximately 80% of the global population relies on herbal remedies for aspects of primary healthcare. The demand for medicinal plants, estimated at over USD 14 billion annually in 2003, is projected to exceed USD 5 trillion by 2050. In India, the medicinal plant trade is valued at around USD 1 billion per year. Despite its vast biodiversity and traditional knowledge base, India contributes only about 0.5% to the global Medicinal and Aromatic Plants (MAPs) export market, whereas China exports MAPs worth nearly ₹18,000 crores annually.

Until the 18th century, although the therapeutic uses of plants were well known, their active constituents remained unidentified. Advances in modern science enabled the isolation and characterization of bioactive compounds, which are now widely synthesized for pharmaceutical use. Nevertheless, traditional plant-based medicine continues to play a crucial role in healthcare systems, particularly in India, where nearly 70% of the rural population depends on herbal remedies. Even in Western countries, about 40% of the population reportedly uses herbal medicines.

Growing concerns over the side effects and high costs of synthetic drugs have renewed global interest in plant-based therapies. Medicinal and aromatic plants not only serve as sources of healthcare but also contribute significantly to livelihoods and economic development. Approximately 30% of modern pharmaceuticals are derived from plant-based compounds, highlighting their continued relevance. The global MAPs market is expanding at an estimated annual growth rate of 12–15%.

India, often referred to as the "botanical garden of the world," harbors immense plant diversity due to its varied agro-climatic zones, including the Himalayas and tropical regions. The country is home to about 45,000 plant species, of which nearly 3,000 are officially recognized for medicinal use, while traditional practitioners utilize more than 6,000 species. The Indian Himalayan Region (IHR) alone hosts over 1,748 medicinal plant species, including herbs, shrubs, and trees with significant therapeutic value.

Among these, *Acorus calamus* L., commonly known as Sweet Flag, is an important aromatic medicinal herb belonging to the family Acoraceae. It is a semi-aquatic, perennial monocot that grows up to 2 meters in height and is characterized by creeping rhizomes. The rhizomes and leaves contain essential oils rich in α- and β-asarone, along with other constituents such as eugenol, methyl eugenol, camphor, linalool, and linolenic acid.

Hydro-distillation is the most commonly used method for extracting essential oil from powdered rhizomes. Factors such as harvesting season, drying methods, distillation time, and extraction techniques significantly influence the oil yield and composition. Due to its diverse phytochemical profile, Acorus calamus exhibits a wide range of pharmacological activities, including sedative, central nervous system depressant, anticonvulsant, antispasmodic, cardiovascular, hypolipidemic, immunosuppressive, anti-inflammatory, antioxidant, antimicrobial, and antidiarrheal properties.

The plant typically grows in marshy soils, shallow waters, and along the margins of ponds and streams in temperate and subtropical regions. In India, it is naturally distributed in the Himalayan region, including states such as Jammu & Kashmir, Himachal Pradesh, Uttarakhand, and Manipur, and is also cultivated in several other states. In Himachal Pradesh, it is commonly found in humid areas near water bodies across districts such as Chamba, Solan, Kinnaur, Kullu, Mandi, Shimla, Kangra, and Sirmaur, at altitudes up to 2,600 meters.

Acorus calamus is known by several common names, including sweet flag, sweet root, and calamus. Although native to India, it is now distributed widely

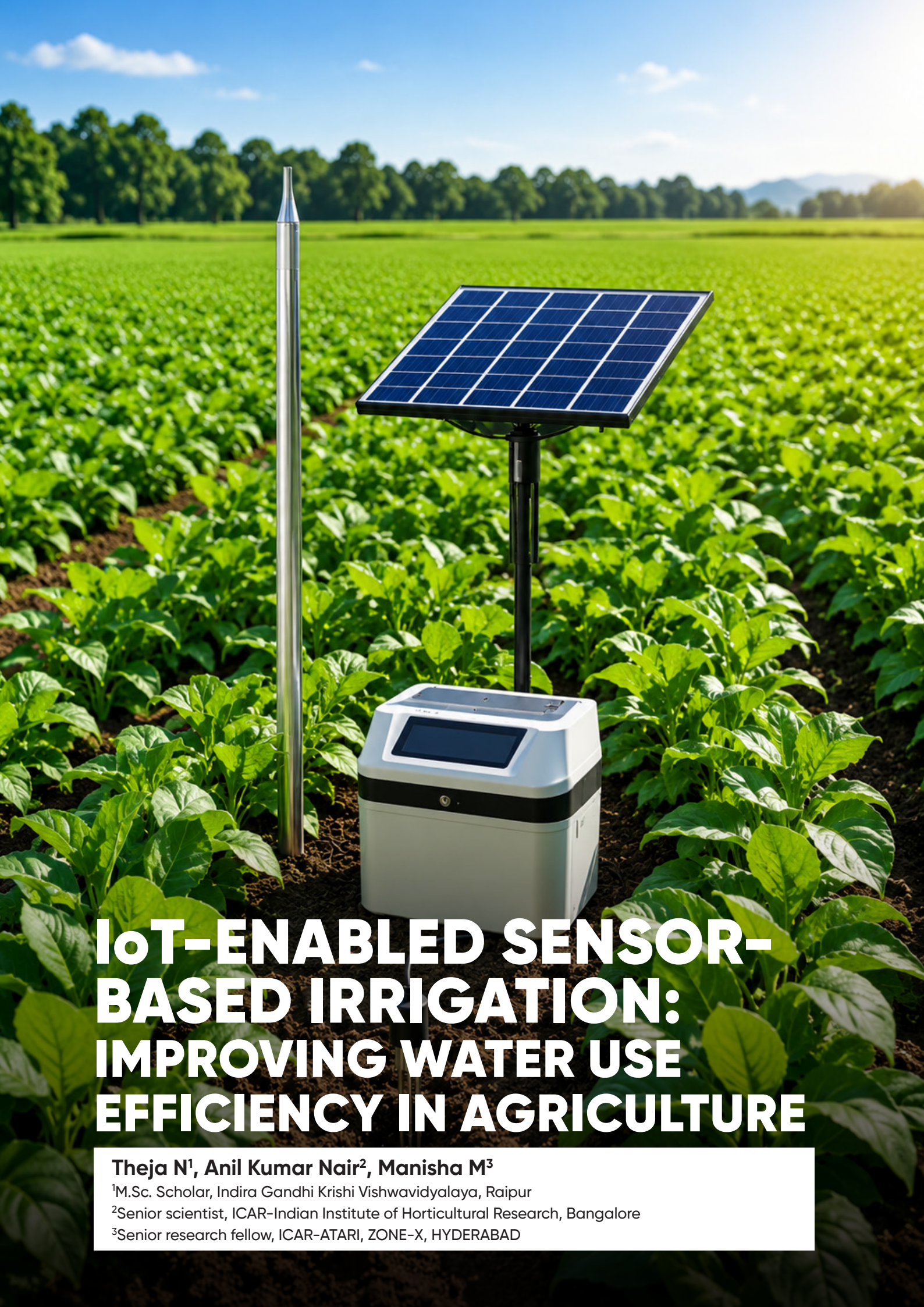
Acorus calamus rhizomes

Natural populations

across Europe, Asia, and North America. Morphologically, the plant has elongated, grass-like leaves with an off-center midrib, emitting a characteristic sweet aroma when crushed. The rhizome, which is cylindrical, woody, and aromatic, serves as the primary medicinal and economic part of the plant.

Traditionally, the rhizome has been used for its carminative, antispasmodic, expectorant, anthelmintic, and nervine properties. It is widely used in the treatment of digestive disorders, respiratory ailments, epilepsy, mental disorders, chronic diarrhea, dysentery, and fevers. In Ayurvedic medicine, it is regarded as a rejuvenating herb for the brain and nervous system. The plant is also utilized in Unani medicine, as well as in perfumery and flavor industries due to its aromatic oil. It is administered in various forms, including powders, oils, balms, pills, and medicated ghee preparations.

Despite its extensive medicinal value and high demand, Acorus calamus is increasingly threatened due to overharvesting from natural habitats. Unsustainable extraction practices have led to a decline in its wild populations, and in some regions, it is considered endangered. Therefore, there is an urgent need for conservation strategies, including cultivation, sustainable harvesting, and documentation of indigenous knowledge. In conclusion, *Acorus calamus* L. is a highly valuable medicinal and aromatic plant with diverse therapeutic applications and significant economic potential. Its rich phytochemical composition and wide-ranging pharmacological properties make it an important resource for both traditional and modern medicine. However, ensuring its sustainable utilization and conservation is essential for preserving this valuable species for future generations.



IoT-ENABLED SENSOR-BASED IRRIGATION: IMPROVING WATER USE EFFICIENCY IN AGRICULTURE

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INTRODUCTION

In recent years, agriculture has faced several challenges, including inefficient use of water resources, excessive reliance on chemical fertilisers, and limited availability of real-time information for effective crop management. Conventional irrigation practices are generally labour-intensive and operate on fixed schedules, often ignoring the actual moisture status of the soil and prevailing environmental conditions. As a result, water resources are frequently overused or poorly managed. The integration of modern technologies like the Internet of Things (IoT) in agriculture is paving the way for smart farming systems. These technologies enable the use of sensors and automated devices to monitor field conditions and support data-driven decision-making. By continuously monitoring soil moisture levels through sensor-based technology, the system provides accurate information that helps maintain the required moisture conditions in the soil.

SMART IRRIGATION METHODS FOR EFFICIENT WATER MANAGEMENT:

Micro-irrigation methods such as drip and sprinkler irrigation improve water use efficiency by delivering water directly to the crop root zone and minimising losses through evaporation and runoff. Soil moisture sensors further improve irrigation management by measuring soil water content and helping farmers decide the correct time and amount of irrigation. Common sensors include capacitance sensors, Time Domain Reflectometry (TDR) sensors, and tensiometers that provide reliable information on soil moisture conditions.

In addition, **remote sensing technologies** such as drones and satellite imagery help monitor crop water stress and field variability using indicators like NDVI. However, integrating these technologies through **IoT-based smart irrigation systems** offers a more efficient solution by connecting sensors, automated devices, and data platforms for real-time monitoring and irrigation control. This approach improves water use efficiency, reduces labour, and supports better irrigation decision-making in modern agriculture. According to Roy et al. (2023), integrating IoT with machine learning helps farmers make better irrigation decisions based on real-time data.

IoT-BASED SMART IRRIGATION SYSTEMS

A Smart Irrigation System based on the Internet of Things (IoT) represents a modern and data-driven approach to agricultural water management. Traditional irrigation methods usually depend on manual operation or fixed irrigation schedules, which often result in over-irrigation or insufficient watering of crops. Such practices lead to inefficient use of water and other resources. In contrast, IoT-based irrigation systems utilise real-time data collected from sensors that monitor soil moisture, temperature, and humidity. Based on this information, the system automatically decides when irrigation is required and how much water should be applied.

IoT-enabled irrigation systems combine sensor data, weather information, and crop requirements to automate irrigation management. These systems collect real-time data from soil moisture sensors and environmental sensors and transmit it to cloud platforms for analysis. Based on the collected data, smart controllers and automated valves regulate water supply, ensuring crops receive the right amount of water at the right time. Farmers can monitor and control irrigation remotely through mobile applications, improving water use efficiency while reducing labour and operational costs.

These systems typically consist of key components such as microcontrollers (e.g., NodeMCU), soil moisture sensors, temperature and humidity sensors (DHT11), relay modules, and water pumps. All these components work together to create a responsive and efficient irrigation system. Communication technologies such as GSM or Wi-Fi enable farmers to monitor and control irrigation remotely through mobile applications or web-based dashboards, making the system suitable for both small gardens and large agricultural fields. IoT-based smart irrigation systems improve water management and support sustainable agriculture.

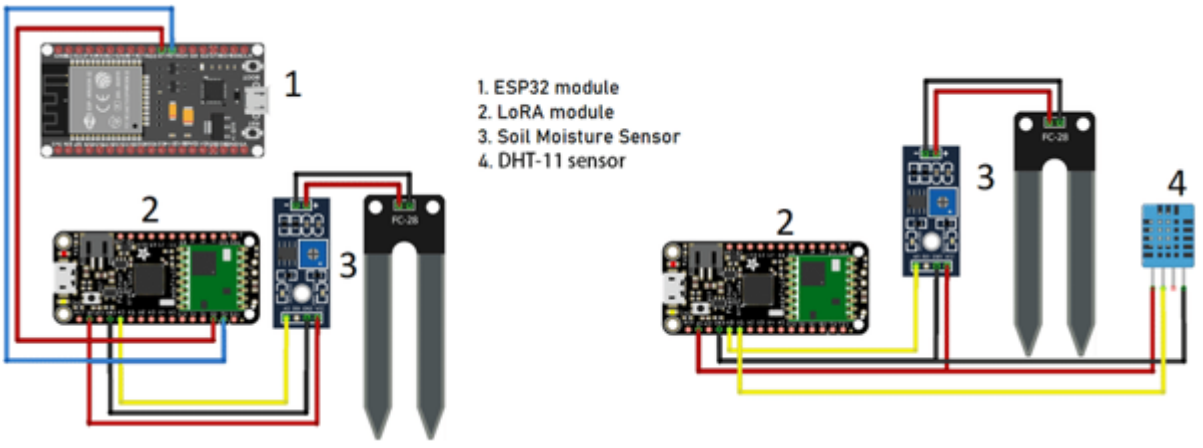

Fig: Components of microcontrollers

IMPLEMENTATION:

The smart irrigation system is designed to automatically supply water to crops based on the moisture level in the soil. Soil moisture sensors continuously monitor the amount of water present in the soil, and when the soil becomes too dry, the system automatically turns on a water pump to irrigate the crops. Once the required moisture level is reached, the pump switches off, preventing excess water use. A small control unit processes the information received from the sensors and manages the irrigation process. In addition, a display screen can show the current system status, while communication modules can send alerts or updates to farmers about irrigation activities. By automating irrigation based on real-time soil conditions, the system helps reduce water wastage, saves labour, and ensures that crops receive the right amount of water at the right time, thereby improving water-use efficiency and crop productivity.

ROLE OF IoT IN AGRICULTURE AND PRECISION FARMING

The Internet of Things (IoT) plays an important role in improving agricultural productivity by enabling efficient monitoring and management of farm resources. It allows farmers to collect real-time data on soil conditions, weather, and crop requirements, helping them manage irrigation and other farm activities more effectively. In drought-prone areas, IoT-based systems help conserve limited water resources and reduce wastage. Precision farming also emphasises monitoring soil parameters such as moisture, temperature, and pH to support better crop growth and higher yields. By integrating sensors with cloud-based platforms, smart irrigation systems can automatically regulate water supply and promote efficient and sustainable agricultural practices.

Key Benefits:

- **Water conservation:** Smart irrigation systems supply water based on real-time soil moisture and weather conditions, significantly reducing water wastage.
- **Improved water use efficiency:** Precise irrigation helps maintain optimal soil moisture levels and reduces deep percolation losses.
- **Higher crop productivity:** Timely and adequate irrigation supports better plant growth and can increase crop yield and quality.
- **Better nutrient uptake:** Controlled irrigation improves the availability and absorption of nutrients by crops while reducing nutrient leaching.
- **Reduced energy consumption:** Efficient water delivery lowers the energy required for pumping and irrigation operations.
- **Lower labour and operational costs:** Automation reduces manual monitoring and irrigation work for farmers.
- **Enhanced water productivity:** Efficient use of water leads to higher crop production per unit of water used.
- **Environmental sustainability:** Smart irrigation minimises water wastage, reduces fertiliser runoff, and promotes sustainable agricultural practices. According to **Mobitech Wireless Solutions,** smart irrigation technologies use sensors, weather data, and automation to optimise irrigation scheduling.

CHALLENGES AND RESEARCH GAPS

- High power consumption of IoT devices used in irrigation systems.
- Exposure of sensors and hardware to harsh field and environmental conditions.
- Weak communication signals and poor network coverage in many rural areas.
- Lack of reliable internet connectivity is affecting real-time data transmission.
- Limited awareness and technical knowledge among farmers about IoT technologies.
- Concerns related to data privacy and security of collected farm data.
- Short battery life of field devices affects long-term system reliability.
- Need for more cost-effective and farmer-friendly smart irrigation solutions.

Furthermore, there are research gaps in developing cost-effective, energy-efficient, and user-friendly smart irrigation solutions that can operate reliably under diverse field conditions. Addressing these gaps is essential for improving the efficiency, scalability, and practical adoption of smart irrigation technologies in agriculture.

FUTURE SCOPE:

Smart irrigation systems can be further improved by integrating advanced technologies such as artificial intelligence (AI) and machine learning (ML) to predict crop water requirements using weather forecasts and past data. The inclusion of solar-powered systems can enhance sustainability and reduce energy costs, especially in remote

farming areas. Integration with IoT cloud platforms can also enable better data analysis and allow farmers to monitor and control irrigation through mobile or web-based applications. In addition, adopting wireless communication technologies such as LoRa or NB-IoT can strengthen connectivity in rural and large agricultural fields, supporting wider adoption and scalability of smart irrigation technologies.

GOVERNMENT POLICIES AND INITIATIVES:

Governments are increasingly promoting the use of Internet of Things (IoT) technologies in agriculture to improve water management and farm productivity. In India, several national schemes support the adoption of sensor-based irrigation and precision farming.

The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)- Per Drop More Crop (PDMC) program promotes efficient water use by providing subsidies of about 55% for small and marginal farmers and 45% for other farmers to install drip and sprinkler irrigation systems.

The Digital Agriculture Mission (India) supports the use of emerging technologies such as IoT, artificial intelligence, and data analytics for real-time agricultural monitoring. Similarly, the PM-KUSUM scheme encourages the use of solar-powered pumps that can be integrated with smart irrigation systems for energy-efficient water management.

Several digital initiatives, such as AgriStack (India), which aims to create digital identities for farmers, and the Krishi Decision Support System (K-DSS), which integrates weather, soil, and remote sensing data, are also helping farmers make better irrigation decisions. The Soil Health Card Scheme further supports precision farming by providing farmers with information on soil nutrients and moisture levels.

In addition to central government programs, several state governments are promoting smart irrigation through additional subsidies and technology-driven initiatives. For example, Telangana provides up to 90–100% subsidy for micro-irrigation systems for small and

marginalised farmers. Karnataka is implementing smart water infrastructure and automated irrigation management under its state water policy. Andhra Pradesh is integrating digital technologies such as e-market platforms and drone-based monitoring to support precision farming, while Goa has promoted sensor-based irrigation systems powered by renewable energy sources. These initiatives collectively support the wider adoption of smart irrigation and precision agriculture in India.

Research and Institutional Initiatives Supporting IoT-Enabled Sensor-Based Irrigation:

The Agri- CRP on Water is a national research initiative aimed at improving water resource management and irrigation efficiency in Indian agriculture. The project focuses on four major themes addressing key research gaps in water management. Theme 1 deals with the development and management of surface water resources and soil moisture in different agro-ecological regions using geospatial technologies. Theme 2 focuses on automated canal irrigation systems for efficient and smart irrigation water management. Theme 3 aims to improve groundwater sustainability by analysing the groundwater energy nexus and its impact on irrigation practices. Theme 4 focuses on the development of IoT-enabled sensor-based smart irrigation systems for automatic and real-time irrigation scheduling.

Under this project, institutions such as ICAR-Indian Institute of Horticultural Research (IIHR), ICAR-Indian Institute of Water Management (IIWM), and Mahatma Phule Krishi Vidyapeeth (MPKV) are working on developing sensor-based irrigation technologies. These systems use soil moisture and weather sensors to automate irrigation and are being tested in farmers' fields for crops such as banana, grapes, cotton, sugarcane, and vegetables. The technology aims to improve water-use efficiency, reduce irrigation water consumption, and support sustainable crop production.

CONCLUSION

IoT-enabled sensor-based irrigation systems represent a transformative approach to modern agricultural water management. By integrating soil moisture sensors, environmental monitoring, and automated irrigation control, these systems enable precise and timely water application based on real-time field conditions. This technology not only improves water-use efficiency but also reduces labour requirements, minimises resource wastage, and enhances crop productivity. Despite challenges such as high initial costs, connectivity limitations, and technical awareness among farmers, ongoing research, technological advancements, and supportive government policies are encouraging the wider adoption of smart irrigation technologies. With continued innovation and institutional support, IoT-based irrigation systems have significant potential to promote precision agriculture, strengthen water conservation, and contribute to sustainable agricultural development in the future.

CLEAN MILK PRODUCTION:
A PUBLIC HEALTH SIGNIFICANCE

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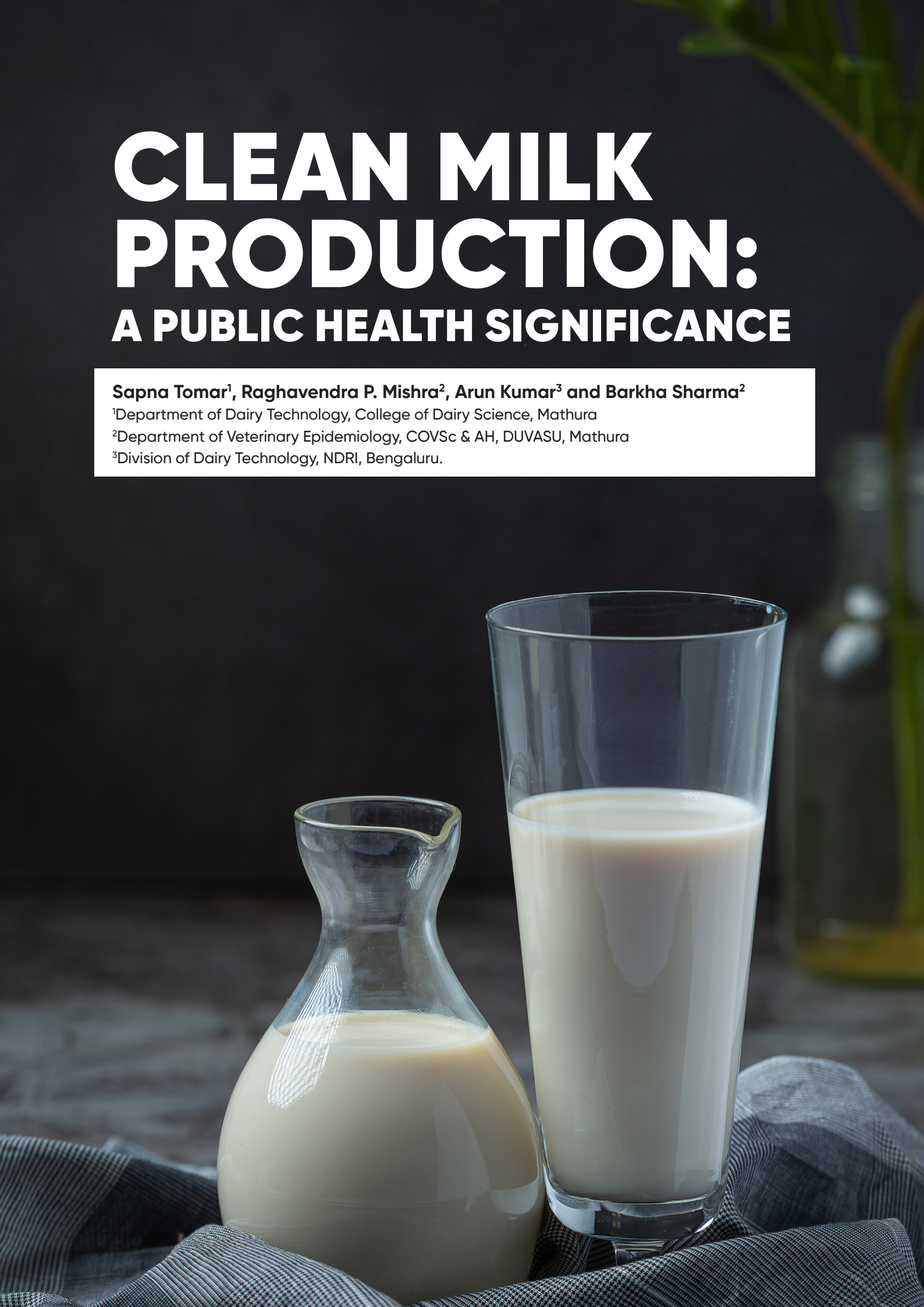

Milk serves as a complete food for the development of both infants and adults. It is also a perfect growth medium for the numerous microorganisms including harmful pathogens. Being a rich source of macro and micronutrients, it is prone to spoilage due to the growth of these microbes. It is also prone to contamination by harmful chemicals, antibiotics, pesticides and adulterants. Indian subcontinent provides a tropical environment that rapidly promotes the growth of spoilage causing microflora. This makes it difficult for farmers to prevent the spoilage of milk due to lack of cold chain. These factors result in huge economic losses to dairy farmers. Thus, it is essential to focus on controlling the quality of milk, pre- and post-secretion. Hence, production of clean milk and maintaining its quality till it reaches the processing plant is an important area of research to safeguard the rights of farmers and consumers. 'Clean milk' is the term that denotes the mammary secretion, secreted by healthy milch animals, and handled under hygienic conditions, which contains small levels of harmless microorganisms, and is free from harmful microorganisms, hazardous chemical residues, pesticides and antibiotics. It should posses good keeping quality without being heat treated. On the other hand, 'Clean Milk Production' refers to the set of preventive measures taken pre- and post-secretion of milk related to animal healthcare practices, disease prevention, production practices, handling of milk, transportation etc. for producing milk which is safe for consumption. The knowledge of possible unhygienic practices that leads to contamination of milk helps in understanding the ground reality and taking preventive control measures by adopting improved strategies. The good hygienic practices that are commonly adopted for clean milk production are classified into different categories, namely:

PRACTICES RELATED TO MILCH ANIMALS

A. Cleanliness of animal

The animals should be groomed before the milking process to prevent the falling of dirt particles from air into the milk. The coat of animals should be washed, brushed and clipped to remove dirt, mud and filth. Timely removal of hairs from hind legs, udder and tail of the animal should be done. Washing of udder and cleaning should be done gently to not to damage the orifices between the quarters of udder. During winters, lukewarm water should be used for udder washing to prevent chills and allow milk let down. Udder can be disinfected by adding hypochlorite (500 ppm) or quaternary ammonium compounds (200-400 ppm) in water. After washing, the udder should be dried before milking using a separate washcloth for each animal. This washcloth should be boiled from time to time for disinfection.

B. Health of animal

Animal should be examined periodically for udder and any sign of infectious diseases like mastitis, tuberculosis etc. If infected, the animal should be treated by a qualified veterinarian. Animals suffering from infectious diseases should be separated and isolated from the herd to prevent the spread of disease. The milk which is obtained from the infected animal should not be pooled with the milk of healthy animals until illness is recovered. Animals should be timely vaccinated for diseases.

PRACTICES RELATED TO MILKING PERSONNEL

The milking personnel should wear clean clothes and should cover their head to prevent falling of hair in milk. They should not smoke, eat, chew anything, spit, etc. during milking. Handler should keep their nails short and clean and always wash their hands before milking using soap and clean water. The hands should be dried with clean towel. Persons with injuries, skin infections and diseases should avoid milking. They should be regularly examined for any health-related issues.

PRACTICES RELATED TO MILKING PROCESS

A. Milking method

Milking should be complete without leaving any milk in the udder after milking. The first few milliliters of milk should be discarded as it contains large number of microorganisms. The forestripping should be collected in a separate utensil and not thrown on the floor as it may attract houseflies and insects near the milking area. Milking should be done with full hands followed by stripping if required. Knuckling should be avoided as it may damage the teats of the animal. The milking process should be completed within 7-8 minutes, if hand milking is adopted. For large herd size, machine milking should be adopted. Dipping the finger in milk and softening the udder should not be permitted. Sick animals should be milked at the end to prevent

infection. Animals should be dried 60-70 days before calving.

B. Milking utensils

The milking utensils should be uniform in size with small mouths to prevent external contamination. They should be free from rust, dents, cracks and crevices. Stainless steel vessels are preferable. The utensils should be washed and scrubbed before and after milking using detergents and chemicals which are non-injurious to health. Use of washing soda with exposure to sunlight or rinsing with hot water or using disinfectants like iodophors is recommended. Cleaned vessels should be kept in inverted position to avoid contamination of bacteria, insects, flies, rodents, mosquitoes etc.

PRACTICES RELATED TO ENVIRONMENT

Contamination from environment can be minimized by paying attention to places where milking, housing and feeding of animals is done. The animal house should be designed and constructed carefully to provide healthy and clean conditions along with access to maximum light and air. Housing should be made of concrete or other hard material, which can be cleaned easily. Housing should be located on high ground compared to the surrounding for proper drainage. It should have adequate supply of clean and fresh water which is piped to animal houses for drinking and cleaning of sheds. Ten to fifteen minutes prior to milking, the floor should be cleaned and dried properly to prevent slipping of animals. Proper ventilation should be there for continuous circulation of fresh air and preventing contamination of milk by odors and gases. Feeding of hay during milking should be avoided as it may enter into milk. Animals should never be fed with spoiled feed affected with moulds or other microbes.

STORAGE OF MILK

Milk collected, should be stored at neat and clean place to prevent any microbial contamination. Adequate facilities should be made for cleaning and sanitizing the utensils/vessels used for milk collection, storage and transport. Sanitizers having smell should not be used to clean the floor of milk room and utensils. Milk should always be kept in clean utensil covered with lid. Milk cans are kept in shade or cool place before loading in the truck.

COOLING OF MILK

Milk should be first strained using clean muslin cloth. The cloth should be tied on the mouth of milk can/vessel to remove the extraneous matter. Muslin cloth used should be boiled time to time to decrease the microbial load. The strained milk should be chilled immediately to below 4°C to prevent the proliferation of pathogenic microorganisms. Bulk milk coolers can be installed to store milk before transportation. The household refrigeration are an alternative to cooling of milk at a small scale. Cooling will retard the growth of both spoilage causing and pathogenic microorganisms.

TRANSPORTATION OF MILK

The temperature of milk should be maintained throughout the transportation of milk from dairy farm to the consumers. Fluctuation in temperature during transportation can deteriorate the quality of milk. Milk is transported from farm to the milk collection centre in small vessels or cans, and then to the chilling centre in small tankers. Milk is loaded in insulated tankers to the processing plant and from the processing plants to the retailer booths.

CONCLUSION

Milk being a highly nutritious entity must be prevented from any source of microbial contamination originating pre- and post-secretion. The highly perishable nature of milk, makes it necessary to safeguard its nutritional value and prevent the loss to dairy farmers. Stringent protocols need to adopted before and after milking process, to ensure the quality of milk. Continuous monitoring of change in the milk quality at farm level is required, which can be done via mobile testing kits, rapid microbiological tests, and testing facilities made available at farmers' doorstep.

Scaling Regenerative Agriculture for Food Security and Climate Resilience in India

A National Convening by The Nature Conservancy & CII FACE

The Nature Conservancy (TNC), in collaboration with the Confederation of Indian Industry Food and Agriculture Center of Excellence (CII FACE), will convene a two-day national conference on Scaling Regenerative Agriculture for Food Security and Climate Resilience in India. Discussions will build on insights from TNC's PRANA (Promoting Regenerative and No Burn Agriculture) programme, which is working across 6,286 villages in Punjab and has engaged more than 650,000 farmers to accelerate the adoption of regenerative agricultural practices.

The convening will bring together senior government officials, farmers, industry leaders, researchers, multilateral organisations and development finance institutions, to explore pathways for scaling regenerative agriculture and strengthening the resilience, sustainability, and productivity of India's food systems in the face of growing climate challenges.

For instance, India extracted 241 billion cubic metres of groundwater in 2023, with nearly 90% used for agriculture, placing immense pressure on water resources. Agriculture and livestock together account for nearly one-fifth of India's total greenhouse gas emissions, with methane from rice cultivation and livestock, and nitrous oxide from fertilizer use driving the bulk of this footprint.

Rice cultivation remains highly resource-intensive, consuming 3,000–5,000 litres of water per kilogram of crop and generating nearly 4 million tonnes of methane emissions each year. Crop residue burning further exacerbates the environmental crisis, contributing to hazardous PM2.5 pollution in Northwest India during October and November.

Against this context, the convening will offer a multi-stakeholder platform to examine evidence-based solutions across the food system. Over the past four years, PRANA has been working with farmers to reduce crop residue burning in Punjab. The programme is also promoting regenerative rice management practices like Alternate Wetting and Drying and Direct Seeding of Rice which aim to reduce groundwater use and methane emissions.

PRANA demonstrates that crop residue burning is driven less by an unwillingness to change and more by operational and economic constraints, including narrow sowing windows, limited access to machinery, and inadequate incentives. Through its interventions to address these constraints, PRANA's journey has led to impact at scale.

Since the 2021 baseline assessment, nearly 700,000 hectares have transitioned to no-burn practices, helping avoid an estimated

3.8 million tonnes of CO_2-equivalent emissions. PRANA has also conserved approximately 400 billion litres of water through its crop residue management and sustainable rice management techniques across Punjab.

Sushil Saigal, Interim Managing Director, Nature Conservancy India Solutions (NCIS), that is assisting The Nature Conservancy on the PRANA programme, said: "Four years of PRANA have shown that sustainable food systems are within reach - if we act together. This convening is an invitation to India's policymakers, industries, scientists, financial institutions, and philanthropists to look at the evidence, engage with farmers who are living this transition, and commit to the investments and policies needed to take it to scale. We are proud to be associated with this moment which is both urgent and timely."

The workshop is spread across two days, where Day One will focus on sustainable agricultural practices and their demonstrated impact, while Day two will highlight innovations in agri-food resilience, financing models, and policy pathways.

Sanjay Sacheti, Co-Chairman, CII National Council on Agriculture and Country Head, Olam Agro, said: "India's food system transformation cannot happen without active private sector participation. Through blended finance, supply chain integration, and industry-led partnerships, there is a significant opportunity to unlock investment that reaches smallholder farmers at scale. CII FACE is committed to facilitating such cross-sector collaboration and we aim to set a concrete agenda for public-private action in the months ahead."

About
The Nature Conservancy

TNC is dedicated to conserving the lands and waters on which all life depends. Guided by science, we create innovative, on-the-ground solutions to our world's toughest challenges so that nature and people can thrive together. We are tackling climate change, conserving lands, waters and oceans at an unprecedented scale, providing food and water sustainably and helping make cities more resilient. We are working to make a lasting difference around the world in 83 countries and territories through a collaborative approach that engages local communities, governments, the private sector and other partners.

CII-Jubilant Bhartia
Food and Agriculture Centre of Excellence

About
CII Food and Agriculture Center of Excellence (CII FACE)

FACE is CII's Centre of Excellence dedicated to building efficiencies across the agricultural value chain from farm to fork. FACE is charged with the mission of improving competitiveness of India' agriculture and food sector by catalysing innovation, building capacity and enhancing productivity across the value chain. FACE works with farmers, companies, development institutions and the government to:

- Improve on and off-farm productivity through the dissemination of best practices and technological innovation.
- Invest in capacity building initiatives and skill development for supply chain participants across the value chain.
- Strengthen linkages across the value chain through market access initiatives, thereby reducing losses and increasing farmer incomes.

FACE's service portfolio comprises commodity specific value chain assessments and supply chain advisory services for food and agri businesses, training and consulting services in the area of food safety, and sectoral research across different market segments. FACE also works on projects in PPP mode, to develop business models that are scalable and replicable across geographies.

HyFun Foods steps into Sustainable Export Logistics and launches new Reefer Rail Transport initiative in collaboration with Adani Logistics and Evergreen Marine Corporation

This first ever dedicated Reefer Rail for HyFun's frozen potato products is replacing up to 40 road trips per shipment, enhancing supply chain efficiency, reducing fuel consumption and lowering carbon footprint.
This initiative is not only complementing but also completing the integrated multimodal (road, rail & Sea) logistics system thanks to the infrastructure development by the Government of India in the past few years.

In a significant step aligned with Hon'ble Prime Minister Narendra Modi's recent call to reduce India's consumption of fuels and adopt more sustainable modes of transportation, HyFun Foods, a pioneer in the exports of frozen potato products, has taken a landmark tripartite initiative with Adani Logistics Ltd. and Evergreen Marine Corporation to create a seamless and environmentally responsible export logistics corridor.

The initiative introduces a dedicated rail freight solution for the transportation of HyFun Foods' frozen products for export. Each such train movement is expected to replace 40 road trips, substantially reducing fuel consumption, road congestion and carbon emissions while ensuring reliable and temperature-controlled movement of products.

The train has been exclusively deployed for the transportation of HyFun Foods' products and will operate from Virochannagar ICD to Mundra Port, part of the integrated logistics ecosystem operated by Adani Ports and SEZ Ltd. (APSEZ), with onward exports handled by Evergreen Marine Corporation, creating an integrated export corridor.

The inaugural run of the dedicated reefer rail service was flagged off on May 21, 2026. "As a leader in the frozen food industry, HyFun Foods has always remained committed to advancing its sustainability initiatives and environmental stewardship through meaningful action. This initiative marks our first dedicated step towards integrating sustainability into our export operations" said Naresh Kapoor, Chief Supply Chain Officer, HyFun Foods.

Kamlesh Karamchandani, Group Executive Director, HyFun Foods, mentioned, "Today, HyFun Foods exports to more than 40 countries across global markets, and this collaboration will further strengthen our export capabilities by enabling more efficient, and sustainably reliable export operations. As we continue to scale our global footprint, this initiative will play an important role in supporting our ambition to expand our presence to over 100 countries in the coming years."

"We are deeply grateful to Adani Logistics Limited and Evergreen Marine Corporation for their partnership and support in bringing this wonderful initiative to life. This initiative will give boost to our endeavour of taking the hard work of Indian farmers to the world by transforming their produce into value-added frozen food products, thereby increasing their incomes " said **Haresh Karamchandani, Group CEO and Managing Director, HyFun Foods.**

About HyFun Foods:

HyFun Foods is one of India's leading manufacturers and exporters of frozen potato products. With a strong presence in domestic and international markets, the company supplies premium-quality products to global quick-service restaurant chains, retail consumers and foodservice partners. HyFun Foods is committed to innovation, sustainability and delivering world-class food solutions.

Mumbai May 13, 2026 **Press Release**

Heritage Foods displays Resilience Amid Severe Milk Supply side challenges and Elevated Input Costs

~ Crosses ₹45,000 Mn Annual Revenue Milestone ~

Heritage Foods Limited (BSE: 519552; NSE: HERITGFOOD), a leading Dairy Company offering milk and Value-added dairy products, announced its results for the year and quarter and year ended March 31, 2026.

Mrs. Brahmani Nara, Executive Director, Heritage Foods Limited alluded to "the company's focus on strengthening procurement infrastructure, expanding distribution reach and scaling high-growth categories. With continued investments in premiumisation, new capacities and Value-added Products, we remain well positioned to drive sustainable long-term growth as industry conditions gradually normalise. Our consumer business continued to deliver healthy momentum led by strong growth across Value-added Products, premium categories and emerging channels. Categories such as curd, paneer, consumer fats and ice-creams recorded strong traction, while Q-commerce and Fresh Distribution scaled rapidly, strengthening market penetration and consumer engagement across key regions. Calibrated pricing actions and improving product mix also supported realisation growth during the year."

Q4 & FY26 RESULTS KEY HIGHLIGHTS

Consumer Business Continues Double-Digit Growth Momentum

The business accelerated momentum delivered healthy growth - revenue grew 10% YoY to ₹11,576 million in Q4FY26 and 9% YoY to ₹45,260 million in FY26 despite weak flush season, milk shortages and prolonged weather-led disruptions across key markets.

Robust Category-Led Growth Across Value Added Products portfolio

VAP revenue grew 18% YoY to ₹3,957 million in Q4FY26 and by 13% YoY to ₹14,678 million in FY26, with VAP contribution improving to 35.5% in Q4FY26 versus 32.5% in Q4FY25 and to 35.3% in FY26 compared to 32.0% in FY25

VAP contribution including consumer-pack fats stood at 41.9% in Q4FY26 compared to 36.8% in Q4 FY25, while FY26 contributed 39.7% versus 36.7% in FY25

Strong VAP momentum continued, with paneer volumes growing 32% YoY in Q4 and 27% YoY in FY26, curd volumes rising

11% YoY in Q4 and 7% YoY in FY26, and ice cream volumes increasing 26% YoY in Q4 and 15% YoY in FY26, reflecting resilient consumer demand and improving product mix.

VAP growth aided by innovations; strong traction seen in new launches viz, Livo Yogurts, premium Sampurna A2 Curd, Nourish+ High Protein Paneer, Alpenvie Ice Cream range, etc.

Elevated Milk pricing and supply tightness, leads to margin shrinkage

Weak flush season across key regions drove average landed milk costs to ₹46.7/litre in Q4FY26, up 8% YoY, one of the sharpest raw milk inflations witnessed by the industry. This resulted in EBITDA margins shrinking by 311 bps to 4.5% YoY.

Procurement Network Demonstrated Resilience Amid Supply Constraints

Despite continued network expansion, severe supply-side challenges resulted in procurement volumes falling 7% YoY to 16.38 LLPD in Q4FY26.

Strong Pricing Discipline and Premiumization partly offset Milk Price Inflation

Timely and calibrated pricing actions along with higher VAP contribution supported blended realisation growth, with milk realisation increasing 4% YoY in Q4FY26 and 4% YoY in FY26, while VAP realisation improved 7% YoY in Q4FY26 and 9% YoY in FY26. Milk sales volumes grew 1% YoY to 11.73 LLPD in Q4FY26 and 2% YoY to 11.83 LLPD in FY26

Heritage Nutrivet Limited Delivers Strong Results

The wholly owned subsidiary, Heritage Nutrivet Limited, recorded a 33% YoY increase in revenue to₹2,454 million in FY26. Profit before tax surged to ₹206 million, underscoring operational excellence and strategic execution.

Commenting further, Mrs. Brahmani Nara, said: "FY26 witnessed one of the toughest operating environments for the dairy industry in recent years, marked by severe milk shortages, elevated procurement inflation and weak flush season. Despite these challenges, Heritage Foods delivered resilient revenue growth of 9% YoY to ₹45,260 million, with quarterly revenues consistently sustaining above the ₹11,000 million mark, reflecting the strength of our consumer patronage and execution capabilities."

Q4-FY26 CONSOLIDATED FINANCIAL PERFORMANCE:

- **Revenue:** INR 11,576 mn - YoY: 10%
- **Gross Margins:** 22% - YoY: (308) bps
- **EBITDA:** INR 522mn – YoY: (35)%
- **EBITDA Margin:** 4.5%-YoY(311) bps
- **PAT: INR 239mn – YoY:** (37)%

One-Time Employee Cost Impact Due to New Labour Codes

The Company recognised a one-time ₹48 million employee benefit provision during FY26 following implementation of the new Labour Codes under Ind AS 19.

Emerging Channels Continued to Scale Rapidly

E-Commerce & Q-Commerce revenues grew 56% YoY, while Fresh Distribution and other emerging channels grew 49% YoY, strengthening urban penetration and channel diversification.

Focused Brand Investments Enhanced Consumer Reach

Strategic campaigns, BIGG BOSS Kannada integration and launch of Certified Organic Cow Milk in Bengaluru strengthened brand visibility and consumer engagement across key markets.

Triumph supports Distinguished Gentleman's Ride Footprint with Record Participation in 2026

2026 marks the 13th consecutive year of partnership between The Distinguished Gentleman's Ride and Triumph Motorcycles

- Over 3700 riders participated across 70+ cities in India, expanding the ride's footprint from 46 towns in 2025
- Triumph has crossed the milestone of 1 lakh motorcycles on Indian roads within just 2.5 years of the launch of the Triumph 400 platform in partnership with Bajaj Auto
- The global ride united classic and modern classic motorcycle riders to raise awareness and funds for prostate cancer research and men's mental health initiatives

Triumph Motorcycles, a brand steeped in over 120 years of motorcycling heritage and passion, successfully concluded another landmark edition of The Distinguished Gentleman's Ride (DGR) across India, further strengthening its role in growing the country's modern classic motorcycling community. Recognized globally as the world's largest charity ride for classic and vintage-style motorcycle enthusiasts, DGR 2026 once again brought together riders across continents in support of prostate cancer research and men's mental health initiatives.

In India, Triumph played a central role in expanding the scale and reach of the Distinguished Gentleman's Ride for the 13th consecutive year. Building on the strong momentum from 2025, which saw

around 3,000 riders participate across 46 towns, the 2026 edition witnessed an 18% increase in participation to 3700, expanding to 70+ cities across the country. Dressed in their sharpest attire and riding classic and modern classic motorcycles, participants celebrated the spirit of style, camaraderie, and purposeful riding - values that continue to define both DGR and the growing Triumph community in India.

Globally, the Distinguished Gentleman's Ride witnessed participation from thousands of riders across 109 countries, reinforcing its position as one of the world's most impactful motorcycling movements dedicated to men's health awareness.

Celebrating the Ride and the Triumph Tribe

The 2026 edition of DGR comes at a significant moment for Triumph in India, with the brand recently crossing the milestone of 1 lakh motorcycles on Indian roads within just 2.5 years of the launch of the Triumph 400 platform in partnership with Bajaj Auto. The milestone reflects the strong resonance of the Triumph brand among Indian riders and the rapid expansion of its rider community across the country.

The success of the Triumph 400 platform has introduced a new generation of riders to the brand, accelerating the growth of modern classic motorcycling in India and strengthening Triumph's connection with riders seeking authenticity, style, character, and community.

At the heart of this growing community are riders who embody the spirit of 'Those Who Know the Difference', discerning riders who value authentic motorcycling experiences, timeless design, craftsmanship, and the deeper sense of connection that riding brings.

With its expanding portfolio, growing dealership footprint, and strong rider ecosystem, Triumph continues to strengthen its position in India's premium motorcycle segment while building one of the country's most engaged riding communities.

Speaking about the Distinguished Gentleman's Ride 2026, **Manik Nangia, President, Probiking, Bajaj Auto Ltd** said, "*The Distinguished Gentleman's Ride has grown into one of the most meaningful global movements in motorcycling, and Triumph is proud to have played a leading role in expanding its scale and participation in India over the years. This year's edition across 70+ cities reflects the strength of our rider community, dealer network, and the passion that riders bring to the Triumph brand. It is especially encouraging to see the ride grow beyond metro markets into newer riding communities across the country. The milestone of crossing 1 lakh Triumph motorcycles on Indian roads within just 2.5 years of the launch of the Triumph 400 platform makes this edition even more special for us. More importantly, it reflects the rise of a new generation of riders who truly are 'Those Who Know the Difference.*"

About Triumph Motorcycles

First established in 1902, Triumph Motorcycles has over 120 years of heritage and remains the UK's largest motorcycle manufacturer. Headquartered in Hinckley, Leicestershire, with manufacturing facilities in the UK, Thailand, Brazil and India, Triumph combines authentic design, character and performance across its Modern Classics, Roadsters and Adventure line-ups – from the iconic Bonneville family to the Street and Speed Triples, the Tiger range, and the accessible new 400cc TR series. In 2023, Triumph entered India in partnership with Bajaj Auto, and has since seen a highly successful response, with the 400cc range establishing a strong foothold in the mid-capacity segment. Together with Bajaj Auto, Triumph is now focused on expanding its presence and building vibrant riding communities across India. In 2023, Triumph also claimed the GUINNESS WORLD RECORDS™ title for the greatest distance travelled on a motorcycle in 24 hours, reinforcing its engineering excellence and spirit of performance.

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