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Transforming Rural Agriculture and Agro-Processing with Smart Village Models

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Abstract- The current paper describes agriculture and agro-processing in the smart village debate as a potential approach to promote sustainable rural development, and identifies a range of challenges, including low-productivity levels, inefficient supply chains, and post-harvest losses in the sector, and offers technology-based solutions such as IoT, big data, precision farming, better irrigation, and new storage technologies. The paper prioritizes the role of effective post-harvest handling, reducing food waste, and equitable market access to producers. With technology, supply chains, and farmer-producer organizations, India can enhance productivity levels, improve incomes, and develop a more effective, technology-enabled agro-processing ecosystem, which meets the food security and economic stability needs of rural communities and the health of other stakeholders in the food systems.

Keywords-Post-harvest management, supply chains, IoT, agribusiness, smart village, rural development.

I. INTRODUCTION

Agriculture is the science of cultivating soil, growing crops, and raising livestock for food products. It plays a crucial role in the economy of many countries, especially the developing ones. Over 50% of India's workforce is engaged in agriculture and allied activities. Agriculture provides food security, acts as a source of raw materials, helps in exporting earnings, boosts the rural market, and improves infrastructure (by investments made in irrigation, storage, etc). Thus, we need to make further improvements in this sector for our betterment. As of 2023, agriculture and other allied sectors contributed approximately 17%-18% to India's GDP. Although the share has declined over the years due to the growth of secondary and tertiary sectors, low productivity, inefficient supply chains, lack of mechanization and dependence on monsoons but in rural areas, agriculture remains a vital source for economic stability, which was further nurtured with the advent of smart villages that emerged as a sustainable development model to address the previously mentioned concerns. A smart village is not merely a digitally connected settlement but a self-sustaining ecosystem that leverages technology, local resources and community participation. At its core, agro-processing and post-harvest management form the foundation of these ecosystems, ensuring livelihood security and economic stability. Agro-processing includes the transformation of raw agricultural products

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into consumable goods. Agro-industry refers to the post-harvest activities involved in the transformation, preservation, and preparation of agricultural production for intermediary or final consumption, typically increasing in importance relative to agriculture and occupying a dominant position in manufacturing as developing countries step up their growth. The Food and Agriculture Organization (FAO,2020) emphasizes that 60% of global population depends on agriculture. In India, the Ministry of Food Processing Industries (2011) reports that the sector contributes around 32% to the food sector GDP (John Wilkinson, Rudi Rocha ,2008)

II. OBJECTIVES

1. Smart village adoption for agriculture and agro-processing.
2. Comparison between the agricultural sector in India v/s other countries.
3. Emphasis is made on post-harvest management, supply chains, expectations, and recommendations along with the challenges.

Agricultural sector in other countries v/s in India. What can we learn from them that benefits our smart village adoption needs?

Agriculture in India is primarily labor-intensive, rainfed, and consists of smaller, subsistence-level farms with a heavy reliance on manual labor and traditional methods. In contrast, agriculture in most other developed countries such as the USA, is capital-intensive, mechanized, and predominantly commercial. Developed nations emphasize advanced technologies, scientific soil management, and higher productivity per unit of land, leading to a smaller proportion of the population engaged in farming and increased returns for farmers.

Indian Agriculture vs Global Agriculture: A Comparative Analysis

Features	*Indian Agriculture*	*Agriculture In Other Countries*
Type Of Farming	Subsistence farming and small landholdings	Commercial farming, capital-inte farms
Labor Dependency	Labor-intensive	Capital-intensive
Technology	Relies on traditional methods	Use advanced machinery
Irrigation	Largely rainfed with a less developed irrigation system	An extensive irrigation system is used
Crop Productivity	Low productivity	High productivity
Crop Variety	Cultivates a limited range of staple crops	Grows a wide variety of crops
Livestock	A smaller extensive sector	A larger intensive sector
Education And Knowledge	Farmers have less access to modern techniques	Farmers are more educated and have access to modern techniques

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III. HOW TO ENHANCE AGRICULTURAL DEVELOPMENT IN INDIA?

Critical Elements of Sustainable Agricultural Development

Sustainable agriculture will require addressing the contributions of many important areas:

I. *Smart Agriculture:*
   a) IoT (internet of things)- smart cameras, web-based sensors, actuators, drones, robots and other advanced agro-devices can be used to automate the decision-making mechanism.(Misra et al, 2022)
   b) Big Data Technology- It can be used for raw material production. Such technologies aim at procuring the best possible raw materials in farming. (Mr.M.Maninda, Dr G.Nedumaran,2020)

II. *Improved Soil Quality*: The presence of soil degradation will require balanced nutrient management and soil health improvement particularly in arid regions. (Seghal foundation,2022)

III. Water Management: As water constraints grow, the management of water through rainwater harvesting, groundwater recharge, and modern systems of irrigation (e.g. drip, sprinkler etc.) for the efficient use of water will be vital. (FAO, 2020)

IV. *Agri-Credit and Crop Insurance:* Access to timely and affordable credit, and agri-insurance policy improvements and reforms can reduce financial uncertainty and can significantly improve farmer productivity and their overall realization of commercial returns/accountability. (Seghal foundation,2022)

V. *Efficient Markets:* Profitable and reliable markets to support fair wages, through improved production planning and other predictable ways to bring utility value and income (Nandan et al., 2020)

Budget 2024: How to enhance the Growth of Agriculture in India?

I. The GVA (Gross Value Added) by the agriculture and allied sectors in India in FY23 stood till US$ 275 billion approximately i.e. 15% of total GVA. The agriculture and allied sectors have a 4% CAGR during the last five years ending in FY23.

II. In FY24, Farmers who are considered as small and marginal farmers, can get financial support through the PM KISAN Yojana, which was about 1.3% of the Union Budget on agriculture with a total of only 1.9% of the Union Budget. The Budget 2024 allocation overall was about 8.3% of major subsidy allocation, including food subsidy for cereals and pulses, fertilizer subsidy, and petroleum subsidy. (Press Information Bureau, 2024)

Post-Harvest Management System

Post-harvest management is an essential feature in minimizing food loss and quality decay after they have been harvested. Without post-harvest management procedures, much of what is harvested can spoil before it reaches the consumer and would have prematurely robbed the farmer of their hard work, and it reduces the availability of food in the supply chain.

This can involve many different processes:

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I. *Harvesting and Handling:* Picking the crops at the right times or handling the crops gently to avoid damaging them. (Kumar et al, 2024)
I. *Grading and Sorting:* Separating high-quality produce from damaged produce or under graded produce so that can achieve the maximum market value and minimize waste.
II. *Storage:* using improved storage systems, i.e., cold storage, silos, etc to reduce spoilage and pests. (Kumar et al, 2024)
III. *Packaging and Preservation:* Preserving produce in transit, and prolonging the shelf life of products through intelligent packaging and techniques, e.g., refrigeration, freeze-drying, or drying. (Kumar et al, 2024)

All of these processes help to maintain freshness, reduce potential waste, and provide better returns for farmers and safer food for consumers (Kachru et al, 2024).

Supply Chain in Agro-Processing:

Essentially, the supply chain is the life cycle of food, from the farm to the consumer's table. The supply chain encompasses farmers, collectors, transporters, processors, warehouses, retailers, and ultimately, the consumer. Unfortunately, not all food makes its journey smoothly. Inefficient bad roads, lack of refrigerated transport, too many "middlemen," and price variations in the market lead to leaks, losses, and reduced profitability to farmers. Farmers are particularly affected for perishable foods like fruits, vegetables, and dairy.

On the flip side, technology is beginning to change the supply chain. Farmers are using mobile applications to market products and connect with buyers directly. Blockchain is allowing the tracking of a product back to its source, creating more trust in consumers. Different models are enabling Farmer Producer Organizations (FPOs) to allow small farmers to aggregate storage and sales for higher margins.(PG Chengappa,2004)

Expectations and recommendations from the sector.

1. Futuristic Growth of India's Food Processing Industry:

With a forecasted value of US$535 billion by 2025-26, growing at a CAGR of over 15%, it is high time to focus on strengthening the food processing value chain in terms of budgetary allocation, and it is evident through schemes such as cluster development and developing micro-processors. Investing in PVAs (Producer Organizations) which are organised under the FPO model , opens a new level of income and market access opportunities. Placing emphasis on encouraging clusters for micro-processing and strong public-private partnerships will pay dividends to farmers in terms of income and market access.

2. Reduce post-harvest losses by upgrading infrastructure

The challenge of reducing post-harvest losses, especially for perishables, and achieving significant value added, can be boiled down to a simple equation: better storage facilities, grading facilities, and transportation networks. Leveraging programs like the Agriculture Infrastructure Fund (AIF) and Mission on

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Integrated Development of Horticulture (MIDH) will be key to modernising and upgrading infrastructure. Building more multi-commodity cooling and grading centres, installing solar micro-grain cooling facilities, and building cooling facilities near strategic airports and ports will reduce food losses, decrease transport costs, and reduce distress selling allowing for more money in the farmers back pocket.

3. Advocating for Agri-Tech Adoption

The agribusiness industry is projected to witness a surge in the adoption of digital technologies, with the Agri-tech market expected to reach US$ 13.5 billion by 2023. To accelerate Agri-tech growth, the government has initiated the Digital Public Agriculture Infrastructure and the Digital Agriculture Mission. AI-enabled precision farming solutions, IoT-enabled live data systems, drone technology and platforms like Agristack will lead to increased income generation opportunities for farmers and agribusinesses. (Somwanshi et al,2016)

4. Growing Agri Export Markets

India's agriculture exports have grown by 6.6% CAGR from FY18 to FY23 with US$ 52.5 billion in agricultural exports in FY23. It focuses on the system's strengths of dealing with farm production, and also on the export systems' ability to be agile and responsive, which will lead to an improvement in the export system's effectiveness, that includes: aligning farmer's produce with the consumer market, developing post-harvest digital supply chain solutions, assuring foreign-built transparency and international quality for agriculture unit exports, and bringing farmers into more export-oriented production. (Somwanshi et al,2016)

IV. CHALLENGES

I. Financial constraints
I. Limited availability of insurance
II. Removal of middlemen
III. Educating the farmers
IV. Financial market values
V. Learning about new technologies and how to use it.
VI. Market export and challenges
VII. Lack of proper branding, packaging and marketing strategies.
VIII. Stringent export regulations.
I. Adverse climatic conditions

V. CONCLUSION

The advent of smart village concepts in agriculture and agro-processing showcased a transformative step towards sustainability and rural development. Post-harvest management and subsequent supply chain is a cart with wheels that cannot move without each other.

What does this mean?

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It means proper agricultural commodity storage without transportation will not help you if it is too late and the quality of the commodity has already degraded. Rapid supply chain development without proper storage leaves you with poor poor-quality commodities. When post-harvest management and supply chain systems are integrated, everyone wins-farmers get more money, consumers get fresh food, and food waste is reduced.

How is the future bright?

We are talking about fancy smart labels on mangoes that tell you how ripe they are or drones that can read the conditions in the storage rooms, which speak directly to the farmers to manage the store and inventory. We are also looking forward to digitally connected markets on our phones that can give the farmers the current price instantly, while protecting them from exploitation and unfair prices. India, if it adopts the above-mentioned technologies, will have mega food parks, modern warehouses, government and industry goals, which will allow and create opportunities for sustainable agro-processing with technology-enabled, better integrated systems.

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