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11. Revitalizing Agriculture Extension Services for Millets in India

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Abstract:

India faces formidable challenges in food and nutritional security, exacerbated by population growth, resource inequality, climate change, and agricultural productivity issues. The prevalence of hunger and malnutrition, especially among children and women, underscores the urgency for sustainable solutions. Millets emerge as a resilient choice, thriving in challenging conditions and offering superior nutritional content compared to traditional staples like wheat and rice. The success of millet cultivation relies on incorporating climate-resilient technologies and establishing comprehensive agricultural practices. This study navigates through the complexities of revitalizing agriculture extension services for millets in India. The analysis draws on a robust dataset of over 32 articles, exploring nutritional profiles, adaptability to diverse agro-climatic conditions, high-yielding cultivars, production data, and government initiatives. Millets, with their exceptional attributes, present a holistic solution to India's food security challenges, offering climate resilience, enhanced livelihoods for small farmers, and improved nutritional outcomes. The study advocates for a comprehensive approach, encompassing equitable resource allocation, climate-resilient agriculture, infrastructure development, and effective nutrition interventions. Embracing millets is pivotal for building a more sustainable and secure future for India.

Keywords:

Climate change, sustainable, climate resilient, resource inequality, hunger and malnutrition.

11.1 Introduction:

India, encompassing Central India, confronts substantial hurdles in ensuring food and nutritional security, driven by escalating population growth, inequitable resource distribution, deficient infrastructure, the impact of climate change, and agricultural productivity challenges. The country's low ranking on the Global Hunger Index underscores the severity of hunger and malnutrition, especially among vulnerable populations like children and women. Climate change intensifies these issues, with erratic rainfall, droughts, and floods disproportionately affecting small and marginal farmers in Central India.

Unsustainable agricultural practices and land degradation exacerbate challenges by diminishing soil fertility and crop yields. Poverty and inequality further impede marginalized communities' access to nutritious food and sustainable livelihoods.

While millets may not occupy a prominent position in Indian agriculture, they play a pivotal role in ensuring food security at both regional and farm levels. Biagetti et al. (2021) highlight the resilience of millets, thriving in adverse conditions such as drought and high temperatures, and their ability to grow with minimal irrigation in areas with low rainfall ranging from 200mm to 500mm. Nutritionally, millets surpass wheat and rice, particularly in mineral content and fiber. Some millets boast over fifty times the fiber content of rice. Finger millet, for instance, provides about thirty times more calcium than rice, and other millets offer at least double the calcium content. Foxtail and little millet also excel in iron content compared to rice.

India grapples with significant food and nutritional security challenges compounded by climate change and inequality. Addressing these issues requires a comprehensive approach encompassing equitable resource allocation, climate-resilient agriculture, infrastructure development, and effective nutrition interventions. Embracing millets as a solution offers numerous advantages, including improved food and nutritional security, climate resilience, and enhanced livelihoods for small and marginal farmers. Promoting the cultivation and consumption of millets is a strategic step toward overcoming these challenges and building a more sustainable and secure future for the nation.

To offer a comprehensive understanding of Nutritional Security and the upliftment of Small and Marginal Farmers in India, we conducted an extensive review covering key aspects such as the Nutritional Profiles of Various Millet Varieties and Other Cereals, the Adaptability of Millets to Diverse Agro-Climatic Conditions in India, Latest High-Yielding Millet Cultivars for Different Regions in India, Production Data of Millets, and Government Initiatives and Policy Support. This thorough review was based on a robust dataset comprising over 32 articles and utilized reputable sources, including Web of Science, Google Scholar, and the Food and Agriculture Organization of the United Nations (FAO) databases, spanning from 1995 to the present.

Our methodological approach followed established and widely accepted procedures, with the following steps:

- **Commence the Research Quest:** The journey began by initiating a pertinent research topic, setting the course for exploration.
- **Structuring and Archiving Relevant Research Materials:** Collected research materials were organized and stored systematically, creating a knowledge repository for further investigation.
- **Data Scrutiny and Distillation for Knowledge Construction:** Detailed data analysis was conducted to extract valuable information, which was then synthesized to build a base of understanding.
- **Discerning Critical Insights from Chosen Sources:** Essential data points were meticulously gleaned from the selected documents, refining the focus on key information.

- **Presentation of Insights Visually, with Proper Attributions:** The acquired information was elegantly presented, incorporating both textual and visual elements, all accompanied by accurate citations.

This systematic and comprehensive approach ensured the reliability and depth of the information gathered, providing a robust foundation for our exploration of Nutritional Security and the well-being of Small and Marginal Farmers in India.

11.2 Nutritional Composition of Millets:

11.2.1 Health Benefits of Millets:

The nutritional profile of millets positions them as a powerhouse of health benefits, offering a robust combination of dietary fiber, protein, vitamins, and minerals. Supported by data and references, the health advantages of incorporating millets into one's diet are underscored by their exceptional nutritional density compared to major cereals like rice and wheat. Millets stand out as a rich source of essential nutrients, boasting higher levels of protein, dietary fiber, and minerals. For instance, pearl millet is notable for its iron and zinc content, while finger millet is recognized for its calcium richness. Scientific studies, such as Rathore et al. (2019), have confirmed the superior nutritional profiles of millets, emphasizing their potential to contribute to improved overall health and well-being. Beyond their nutritional richness, millets play a pivotal role in the prevention and management of chronic diseases. The high fiber content in millets has been linked to regulating blood sugar levels, thereby reducing the risk of type 2 diabetes. Furthermore, millets contain antioxidant compounds that combat oxidative stress and inflammation associated with cardiovascular disorders. Research, including that by Tripathi et al. (2023), underscores the significant role of millets in managing diabetes and lowering the risk of cardiovascular diseases, attributing these benefits to their low glycemic index, high fiber content, and beneficial phytochemicals. Weight management and digestive health are additional facets where millets shine. The fiber content in millets promotes satiety, aiding in weight management by preventing overeating. Millets also contribute to digestive health by providing dietary fiber, which regulates bowel movements and maintains a healthy gut. Studies, like that conducted by Arora et al. (2023), suggest that millet-based meals induce increased feelings of fullness and reduced energy intake compared to rice-based meals, highlighting their potential in weight management. Moreover, the fiber in millets supports healthy digestion, potentially alleviating issues like constipation and promoting overall gastrointestinal well-being. In essence, the incorporation of millets into one's diet emerges as a holistic approach to enhance nutritional intake, manage chronic diseases, and support weight management and digestive health. Backed by scientific evidence, millets offer a promising avenue for promoting overall well-being and addressing contemporary health challenges.

11.2.2 Adoptability of Millets to Diverse Agro-Climatic Condition in India:

Millets stand out as agricultural marvels, showcasing remarkable adaptability across diverse agro-climatic zones in India. Cultivated extensively in states such as Maharashtra, Karnataka, Rajasthan, Andhra Pradesh, Telangana, and Tamil Nadu, millets thrive in a spectrum of environments. Their versatility and ability to flourish in varied conditions make

them well-suited for cultivation throughout the country. The adaptability of millets is particularly evident in their cultivation across arid, semi-arid, and sub-humid regions. Traditional millet varieties like pearl millet, finger millet, foxtail millet, and sorghum have been cultivated for generations in these distinct agro-climatic zones. This adaptability not only contributes to the resilience of millets but also positions them as valuable crops for sustainable agricultural practices. One of the key strengths of millets lies in their ability to withstand challenging environmental conditions. With inherent climate resilience, millets demonstrate a capacity to endure drought, high temperatures, and low soil fertility. This characteristic makes them especially well-suited for arid and semi-arid regions, where water scarcity and challenging growing conditions are prevalent.

The widespread cultivation of millets across states and agro-climatic zones underscores their importance for ensuring food security in India. Their adaptability allows farmers to diversify their crops, mitigating risks associated with climate variability. By harnessing the unique qualities of different millet varieties, agricultural practices become more resilient and sustainable. In conclusion, the adaptability of millets to diverse agro-climatic conditions in India highlights their significance as a valuable and resilient crop. As the country faces the challenges of climate change and varying environmental conditions, the cultivation of millets emerges as a strategic and sustainable approach for ensuring food security and fostering agricultural resilience.

11.2.3 Synergistic Influence of Technology, Policy and Market Forces On Millet:

The cultivation and production dynamics of food crops, including millets, have undergone significant changes over the past six decades, influenced by a complex interplay of technology, policy, and market forces. Millets, despite their nutritional benefits and adaptability, face unique challenges that have shaped their production trends differently from major cereals like wheat, rice, and maize. Over the years, millet productivity has shown commendable growth, with pearl millet leading the way with a 3.45-fold increase, comparable to the growth seen in wheat and maize (Etesami & Maheshwari, 2018). However, unlike wheat and rice, the market demand for millets, especially pearl millet, remains low. This is attributed to a lack of policy and market-driven demand, leading to a decline in cultivation despite notable productivity gains.

Sorghum, finger millet, and small millets have experienced doubling of productivity, yet their production trends diverge from the success stories of wheat, rice, and maize. While wheat production has surged eight-fold due to technological advancements, extensive cultivation, and policy support, rice production has tripled, thanks to a collaborative effort between scientists, policymakers, and farmers. Maize, with a five-fold increase, has thrived due to heightened demand from the poultry industry and other sectors.

In contrast, millets face unique challenges in terms of market demand and remuneration. Despite increases in minimum support prices (MSP) for sorghum and pearl millet, their economics of cultivation are not significantly influenced as they are not procured by government agencies. The MSP of wheat and rice, being higher than that of millets, further complicates the economic viability of millet cultivation. The decline in cultivation of millets, including sorghum and finger millet, is noticeable in states like Maharashtra, Karnataka, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Tamil Nadu, Rajasthan,

Uttarakhand, Haryana, and Gujarat. This shift is primarily due to the replacement of millets with more remunerative alternatives like maize, cotton, mungbean, and soybean. The complex dynamics surrounding millet cultivation highlight the need for a holistic approach that addresses not only production and productivity but also market demand, policy support, and remuneration.

It is essential to develop strategies that recognize the unique challenges faced by millets in the contemporary agricultural landscape and work towards creating an environment conducive to their sustainable cultivation and widespread adoption.

Table 11.2: Natritional Profile and Different Millets and Other Cereal Nutrient Composition of Millets and Other Cereals (per 100g edible portion; 12% moisture [14,15])

Food	Protein*(g)	Fat (g)	Ash (g)	Crude fiber (g)	Carbohydrate (g)	Energy (kcal)
Rice (brown)	7.9	2.7	1.3	1.0	76.0	362
Wheat	11.6	2.0	1.6	2.0	71.0	348
Maize	9.2	4.6	1.2	2.8	73.0	358
Sorghum	10.4	3.1	1.6	2.0	70.7	329
Pearl millet	11.8	4.8	2.2	2.3	67.0	363
Finger millet	7.7	1.5	2.6	3.6	72.6	336
Foxtail millet	11.2	4.0	3.3	6.7	63.2	351
Common millet	12.5	3.5	3.1	5.2	63.8	364
Little millet	9.7	5.2	5.4	7.6	60.9	329
Barnyard millet	11.0	3.9	4.5	13.6	55.0	300
Kodo millet	9.8	3.6	3.3	5.2	66.6	353

** All values except protein are expressed on a dry weight basis*

Table 11.3: Comparative Analysis of Vitamin, Macro and Micro Nutrient Content of Different Millets Other Cereals [14,15]

Food	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Rice (brown)	33	1.8	0.41	0.04	4.3
Wheat	30	3.5	0.41	0.10	5.1
Maize	26	2.7	0.38	0.20	3.6
Sorghum	25	5.4	0.38	0.15	4.3
Pearl millet	42	11.0	0.38	0.21	2.8
Finger millet	350	3.9	0.42	0.19	1.1
Foxtail millet	31	2.8	0.59	0.11	3.2
Common millet	8	2.9	0.41	0.28	4.5
Little millet	17	9.3	0.30	0.09	3.2
Barnyard millet	22	18.6	0.33	0.10	4.2
Kodo millet	35	1.7	0.15	0.09	2.0

11.3 India Millets Production:

India stands as the global leader in millet production, particularly excelling in the cultivation of two primary varieties – pearl millet (bajra) and sorghum (Jowar). In 2020, India contributed significantly to the world's millet production, collectively accounting for around 19%. The individual contributions of pearl millet and sorghum were noteworthy, representing 40.51% and 8.09%, respectively, of the global millet production in the same year. The key millet-producing states in India play a crucial role in the country's dominance in millet cultivation. States such as Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, and Uttarakhand collectively contributed to approximately 98% of India's millet production during the 2020-21 period. Among these, Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, and Gujarat emerged as the primary contributors, accounting for over 83% of the total millet production. Rajasthan led the way with a substantial share of 28.61%. India's rich agro-diversity is reflected in the wide range of millet varieties cultivated across the country. The diverse millet portfolio includes pearl millets, sorghum, finger millet, foxtail millet, kodo millet, barnyard millet, proso millet, little millet, and pseudo millets like buckwheat and amaranths. Among these varieties, pearl millet (bajra), sorghum (Jowar), and finger millet (Ragi) hold the predominant share in India's overall millet production. The success of India as the leading millet producer underscores the agricultural prowess and adaptability of millets to diverse agro-climatic conditions across the country. Millets not only contribute significantly to India's food security but also play a crucial role in promoting sustainable and diversified farming practices, aligning with the nation's rich agricultural heritage.

11.4 Opportunity for Value Addition, Processing and Entrepreneurship in Millets Based Enterprise:

The demand for millet-based products is experiencing a notable upswing, driven by their recognized nutritional benefits and sustainable characteristics. Millets offer a diverse array of product options that cater to various consumer preferences, making them an attractive choice for health-conscious individuals seeking nutritious and gluten-free alternatives. The health and wellness sector, which is witnessing significant growth worldwide, provides a fertile. market for millet-based entrepreneurship. Millets also hold regional and cultural significance, particularly in India, where they are deeply rooted in traditional diets and culinary practices. This creates opportunities for entrepreneurs to tap into local and regional markets by offering authentic millet-based products that resonate with specific community preferences and leverage cultural heritage. This localized approach enhances market acceptance and fosters a sense of authenticity among consumers. Moreover, millets have export potential, appealing to health-conscious consumers and international markets interested in sustainable and nutritious food options. Entrepreneurs can explore opportunities to export millet-based products, leveraging the growing demand from Indian diaspora communities and the increasing global interest in healthier eating habits. To fully capitalize on the potential of millets, it is essential to invest in modern processing infrastructure. Establishing well-equipped processing units that facilitate efficient production, improved product quality, and scalability is crucial. By investing in technology and infrastructure, entrepreneurs can meet the growing market demand while maintaining consistent standards and competitiveness.

11.5 Challenges in Millets Production, Promotion and Market Access in India:

Millets face several challenges in production, promotion, and market access in India. These challenges hinder the growth and widespread adoption of millets as a sustainable and nutritious food source as follow:

- Low productivity is a challenge in millet cultivation, hindering widespread adoption. Research and development of high-yielding millet varieties is crucial to overcome this challenge.
- Limited awareness and promotion of millets have led to a lack of consumer demand and market acceptance. Creating awareness about the nutritional benefits, sustainability, and versatility of millets is essential to drive consumer interest and increase their demand.
- Insufficient value chain infrastructure in the millet sector, including processing, storage, and distribution, hinders its growth. Limited facilities and inefficient systems lead to post-harvest losses, compromising product quality. Developing a robust and efficient value chain infrastructure is crucial to ensure high-quality millet products and improve market access.
- Limited market linkages pose challenges for millet farmers in accessing markets and obtaining fair prices. Strengthening market linkages and providing farmers with better market information are crucial to enhance market access for millets.
- Policy support is essential for promoting millet production and market access, but the current policy environment for millets in India lags behind that of major crops. Implementing policies that incentivize millet cultivation, prioritize research and development and facilitate market access for millet-based products can greatly benefit the sector.

11.6 Government Initiatives Policy Support:

The government of India has implemented several initiatives and policies to support millets and promote their cultivation, production, and market access. Some key government initiatives include: National Mission on Sustainable Agriculture (NMSA): NMSA focuses on promoting sustainable agricultural practices, including the cultivation of millets (Kadaba et al., 2023).

It aims to enhance productivity, conserve natural resources, and improve farmers' livelihoods through the adoption of climate-resilient and eco-friendly practices. National Food Security Mission (NFSM): NFSM aims to increase the production of food grains, including millets, to ensure food security in the country.

The mission provides financial and technical support to farmers for the adoption of improved technologies, inputs, and best agricultural practices. Pradhan Mantri Kisan Sampada Yojana (PMKSY): PMKSY focuses on the development of food processing infrastructure, including millet processing units. It provides financial assistance and incentives to promote value addition, processing, and market linkage for agricultural produce, including millets. Minimum Support Price (MSP): The government declares MSP for certain millet crops, providing price support to farmers and ensuring remunerative prices

for their produce. This helps in stabilizing farmers' income and incentivizing millet cultivation. National Institute of Nutrition (NIN): NIN conducts research and provides scientific in-puts on the nutritional aspects of millets. It contributes to creating awareness about the health benefits of millets and supports the formulation of policies related to nutrition and millet promotion. Public Distribution System (PDS): Millets are included in the PDS to ensure their availability and affordability for consumers, particularly in regions where millets have cultural significance. This helps in creating a market for millet-based products and increasing consumer demand.

11.7 Significance of Millets as A Solution for Small and Marginal Farmer:

Millets hold immense significance as a solution for small and marginal farmers in India, providing a range of benefits that directly address the challenges faced by these farmers. Millets are highly resilient to adverse climatic conditions, including drought and high temperatures, making them ideal for cultivation in regions with limited access to irrigation facilities.

Their ability to thrive in such conditions helps mitigate the risks associated with climate variability and offers a reliable source of income for small farmers. Another key advantage of millets is their low input requirements.

They are known for their ability to grow well in low-nutrient soils, reducing the need for expensive fertilizers. Millets also have natural resistance to pests and diseases, reducing the dependency on pesticides.

These factors contribute to lower production costs and make millet cultivation financially viable for small and marginal farmers with limited resources. Millets are nutritionally dense and offer a diverse range of nutrients, including dietary fiber, protein, essential minerals, and antioxidants.

They have high levels of micronutrients such as iron, calcium, magnesium, and zinc, addressing the issue of malnutrition prevalent among small farmers and rural communities. Incorporating millets into the diet can significantly improve the overall nutritional security and well-being of farmers and their families. In terms of income generation, millets offer multiple opportunities. They can be processed into a variety of value-added products such as millet flour, flakes, snacks, and ready-to-eat meals.

This opens avenues for small-scale processing units and local enterprises, empowering farmers to diversify their income streams and tap into the growing market demand for healthy and nutritious food products. Additionally, millets contribute to crop diversification, reducing the risks associated with mono-cropping and promoting sustainable farming practices. By incorporating millets into their cropping systems, small and marginal farmers can enhance soil health, conserve water, and reduce the reliance on chemical in-puts.

The environmental sustainability of millets is another significant factor. They have a low carbon footprint and are well-adapted to agro-ecological farming systems. Numerous farmer associations have been

List 11.1: Government initiatives and policy support for millets vary across different states in India

Sr. No.	State Name	Government Initiatives and Policy
1	Karnataka	The state government of Karnataka has launched the “Siridhanya Mission” to promote millets. It includes various programs and policies to encourage millet cultivation, provide financial support to farmers, establish millet processing units, and create market linkages.
2	Telangana	The state government of Telangana has implemented the “Telangana State Millets Development Program” to promote millet cultivation and consumption. The program includes measures such as providing subsidies for millet seeds, offering technical support to farmers, organizing training programs, and creating market infrastructure for millet-based products.
3	Andhra Pradesh	The government of Andhra Pradesh has initiated the "Rythu Sadhikara Samstha” program, which focuses on promoting millets and other traditional crops. It includes capacity-building programs for farmers, promotion of organic farming practices, and establishment of millet processing and marketing infrastructure.
4	Tamil Nadu	The government of Tamil Nadu has launched the “Millet Mission” to encourage millet cultivation and consumption. The mission involves providing support to farmers in terms of subsidies, training, and access to markets. It also aims to create awareness about the health benefits of millets through campaigns and educational programs
5	Maharashtra	The government of Maharashtra has implemented the “Mukhyamantri Satyagraha Millet Scheme” to promote millet cultivation and improve farmers’ income. The scheme provides financial assistance, training, and support for millet production, processing, and marketing.
6	Rajasthan	The government of Rajasthan has implemented the "Millet Mission" to promote millet cultivation and consumption. The mission focuses on enhancing millet productivity, providing technical support to farmers, creating market linkages, and promoting millet-based products through branding and marketing campaigns.
7	Madhya Pradesh	The government of Madhya Pradesh has launched the "Millet Mission" to promote sustainable millet cultivation and improve farmers' livelihoods. The mission includes activities such as capacity-building programs, distribution of improved millet varieties, support for organic farming practices, and establishment of millet processing and marketing infrastructure.

Sr. No.	State Name	Government Initiatives and Policy
8	Odisha	The government of Odisha has initiated the "Millets Mission" to encourage millet cultivation and consumption. The mission aims to improve millet productivity, support farmers through training and subsidies, promote millet-based entrepreneurship, and create market linkages for millet products.
9	Uttar Pradesh	The government of Uttar Pradesh has taken measures to promote millets under its "Uttar Pradesh Agro-Climate Regional Plan." The plan includes promoting millets as a climate-resilient crop, providing support for millet cultivation and processing units, and creating market linkages for millet-based products.
10	Gujarat	The government of Gujarat has implemented the "Gujarat Millet Mission" to promote millet cultivation, processing, and marketing. The mission focuses on creating awareness about millets, providing technical assistance to farmers, establishing millet processing units, and developing market linkages for millet-based products.

Established overtime to aid small and marginal farmers in overcoming obstacles to millet production and sale. Market instability is a common occurrence, thus policies that safe-guard farmers' livelihoods are necessary. Incentivizing the adoption of inter-cropping and providing crop insurance and support for storage facilities will foster income and food security. In conclusion, millets offer a range of benefits that make them an ideal solution for small and marginal farmers in India.

Their resilience to adverse climatic conditions, low input requirements, nutritional richness, income-generating potential, crop diversification bene-fits, and environmental sustainability make them a valuable resource for improving the livelihoods and food security of small-scale farmers. Encouraging millet cultivation and promoting their consumption can contribute to a more resilient, inclusive, and sustainable agricultural system in India.

11.8 Conclusion:

In conclusion, millets hold great promise as a solution for addressing the complex challenges of food and nutritional security, climate resilience, and livelihood improvement in India. With their nutritional richness, adaptability to diverse agro-climatic conditions, and income-generating potential, millets offer a sustainable and inclusive pathway for small and marginal farmers.

Government initiatives and policies, along with market demand and technological advancements, play a crucial role in promoting millet cultivation, processing, and market access. By embracing millets as a key component of agricultural systems, India can enhance food and nutritional security, mitigate climate risks, and empower small farmers to build more resilient and sustainable livelihoods.

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