Millets traditions, science and technology in Nepal (BK Joshi, RK Shrestha, KH Ghimire, HB KC, and A GC; eds). 2023. NAGRC, CCDABC and FAO; Kathmandu.

# Revival of Future Smart Foods for Sustainable Food Systems in Nepal: A case of Millets

Oshin Sharma, Rajendra Dhakal, Abid Hussain and Kamal Aryal

ICIMOD, Kathmandu, Nepal; OS: oshin.sharma@icimod.org; RD: rajendra.dhakal@icimod.org; AH: abid.hussain@icimod.org; KA: kamal.aryal@icimod.org

## Abstract

Millets are one of the Future Smart Foods (FSFs), indigenous to Nepal. Millets are rich in micronutrients, more resilient to water and heat stresses and can be cultivated in marginal lands and at different altitudes ranging from plain terai to high hills. They can contribute to the overall sustainability of food systems through their potential contribution to nutrition security, rural income, and resilience to climate change. Beyond their immediate agricultural significance, millets offer potential in advancing agro-/eco-tourism and culinary science. This research paper, rooted in rigorous peer review and a SWOT analysis of the current millet landscape, develops an operational framework. This framework, exemplified through the case of millets, outlines a sustainable, long-term approach for the revival of traditional crops, thereby ensuring the sustainability of food systems in Nepal. In addition to this, the paper provides recommendations that span multiple fronts, including behavioral, technological, market, and policy aspects, to facilitate the revival of millets within the food system. By adopting a holistic approach that considers behavioral changes, technological innovations, market dynamics, and policy measures, we can create an enabling environment for the sustainable revitalization of millets and other FSFs. This comprehensive strategic way will not only contribute to the restoration of agrobiodiversity and dietary diversity but also enhance the resilience of Nepal's food systems in the face of climate change and other challenges.

**Keywords:** Millets, future smart food crop, revival, agricultural policy, indigenous crop

## Introduction

Indigenous crops have been an integral part of the food systems in the Hindu-Kush Himalaya (HKH) for centuries. However, due to several socioeconomic and climatic factors, these crops are gradually declining in the food systems. Due to a decline and underutilization of these crops, these are also called as 'neglected and underutilized species. In 2017, the FAO relabeled these crops as 'future smart foods' in view of their importance for climate change resilience, agrobiodiversity, agriculture sustainability, and food and nutrition security (Hussain and Qamar 2020). Millets are also part of the indigenous crops in Nepal and HKH region and are deeply intertwined with the nation's culture and history. However, along with traditional perception associating millet with lower socio-economic groups and other factors such as evolving dietary preferences due to globalization, limited awareness of their nutritional benefits, restricted market access and a shift toward modern agricultural practices favoring different crops have collectively contributed to a decline in millet consumption (Mal et al 2010) relegating it to the category of neglected and underutilized crops. Recognizing its exceptional nutritional potential, climate resilience, economic viability, and local adaptability, the United Nations Food and Agriculture Organization designated millet as a Future Smart

Food crop in 2018. Furthermore, in 2023, the International Year of Millet is being celebrated with the theme 'Millet Crops for Food Nutrition, Security, Environment, and Rural Transformation.'

In the context of Nepal, Future Smart Food (FSF) crops, including millets, can play a pivotal role in addressing food security, enhancing climate resilience, and transforming the rural economy. They have the potential to bridge the growing production and nutrition gaps in our food system (Li and Siddique 2018). Millets, in particular, can serve as a compelling entry point for advocating the revival and mainstreaming of FSFs in Nepalese agriculture. However, it is essential to recognize that these efforts should not be limited solely to millets. A comprehensive, long-term plan is needed to integrate a wide range of FSFs into our agricultural practices. This paper aims to develop an operational framework, using millets as an example, to guide the long-term revival of traditional crops and ensure the sustainability of our food systems in Nepal.

## Methodology

This study is secondary research conducted based on the existing scientific literature and government reports to analyze the status of millet in current food system. Literature is mainly searched from ResearchGate, Nepalese agriculture research journals and Google Scholar based on relevant keywords search including neglected and underutilized species, millets, seed system, mechanization, market, and ethnobotany. Following the literature review, SWOT analysis is conducted focusing on both production and consumption side of the millet food system and finally recommendations are drawn for revival and mainstreaming. In this process will also develop an operational framework with an example of millets for long term revival of traditional crops for sustainability of food systems in Nepal.

## FSFs and Food System

For centuries, people across Nepal have utilized a diverse array of nourishing foods. They held a profound understanding of edible food sources within their ecosystem, ranging from wild edibles and medicinal plants to domestically cultivated cash crops (Joshi 2022). Regrettably, due to the forces of increasing globalization, agricultural intensification, and demographic shifts, newer generations are gradually distancing themselves from many of these traditional foods (De Bruin et al 2021). This trend has led to an interruption in the transfer of valuable knowledge, resulting in a rise in food monotony. This shift poses potential issues such as an increased risk of micronutrient deficiency, diminished resilience within the food system, compromised food sovereignty and loss in agrobiodiversity.

In Nepal, demographic and health survey of 2022 states that 69% of children aged 6–23 months consumed unhealthy foods. And throughout the country 30% of children under five-year age are stunted, and 22.3 % children are underweight, of which mountain kids are the most suffering from stunting. Future Smart Food, as defined by the FAO, encompasses Neglected and Underutilized Species (NUS) that are rich in nutrition, resilient to climate variations, economically viable, and locally available or adaptable. These crops are now being considered essential entry points for transforming nutritional and agricultural challenges into opportunities in rural settings (Adhikari et al 2017, Li et al 2019).

Millets are Future Smart Foods, indigenous to Nepal. Compared to popular cereal crops, millets are resilient. Their ability to thrive in marginal lands, resist pests, excel in intercropping setting, coupled with their nutrient-dense composition, makes them a compelling choice for enhancing food and nutritional security and ecological sustainability (Kumar et al 2018). Furthermore, millets demonstrate adaptability across varying altitudes, rendering them suitable for diverse geographical contexts (Khadka et al 2016). Importantly, millets are deeply ingrained in the social fabric of Nepal's food culture, enhancing their acceptance and integration within local diets and contribute to local economy.

Food, nutrition, and tradition are societal concerns associated with millets, which are closely intertwined with economic and environmental aspects through fields like ethno-botany and household economics respectively. The potential for income generation from millets also intersects with environmental considerations due to their relatively superior agroecosystem services, including reduced resource pressure, when compared to other major cereal crops (UNRIC 2023). Based on these functions of millet, which addresses all aspects (social, economic, and environmental) of sustainability in Nepalese food system, a framework is presented in **Figure 1**.

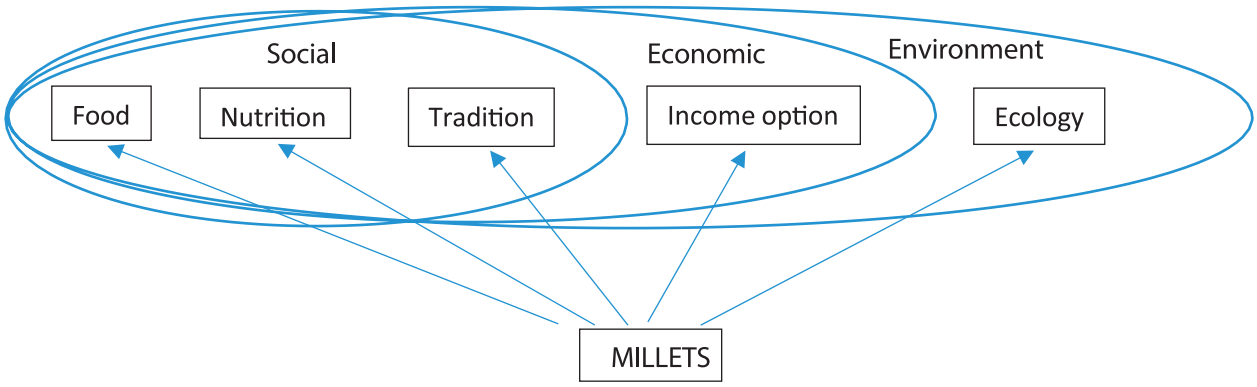


**Figure 1**. The impacts of Millet in food systems (based on the sustainability framework and authors analysis from on literature review)

In Nepalese food system, millets are used as cereal crop, animal fodder, and for making brewery items. Even though use of millet is engraved in our food system, there is some resistance making it underutilized crop. The resistance to consuming millets in Nepal is often rooted in its socio-cultural perception as 'poor man's food.' Grains like rice and wheat, cultivated in more fertile areas with greater resource requirements, have historically been regarded as more desirable and prestigious. In contrast, millets, grown in less fertile regions, have become associated with lower socioeconomic groups. This ignorance towards millet was also observed in policy level as very less attention was given to agricultural research and development (Shrestha et al 2020a) until recently as scientific evidence increasingly underscores millets' nutritional importance and their resilience in the face of climatic events and pest incidence, the integration of these nutrient-rich traditional foods into the broader food system has become more critical than ever. Beyond their immediate agricultural significance, millets also offer potential in promoting agro- eco-tourism and advancing culinary science.

## The Situation of Millets Production and Consumption in Nepalese Food System

Traditional dishes made from millets, such as *dhindo*[1], *kodoko roti*[2], *kagunoko khir*[3], *chinoko bhat*[4], and *Kodoko khole*[5] were once typical local food just a generation ago. However, as discussed earlier, people's preferences have now become limited to food options based on rice, wheat, and maize.

The Annual Household Survey data showing sharp decline in urban consumption and slight decline rural urban consumption of millet in from 2015/16 to 2016/17 suggests a notable change in consumer preferences with only 3.5% household in the nation consuming millet as food option. Similarly, another study examining dietary patterns between 1993 and 2011 revealed that Nepalese consumers gradually

1 Dhindo is made by gradually adding finger millet flour to boiling water while stirring.
2 Kodoko roti is a pancake type flat bread made from thick batter (finger millet) with water and salt or sugar.
3 Kaguno ko kheer is pudding made from proso millet, milk, sugar and dry fruits.
4 Chinoko bhat is rice like food made from proso millet
5 Kodoko khole is soup made from finger millet flour.

shifted from low-cost, calorie-rich foods to more expensive, calorie-dense items. This dietary diversification was made possible due to increased income, changing lifestyles, and other factors (Thapa et al 2019). Another study conducted in a Nepalese village indicated that over the last decade, cash crops like mustard and cardamom replaced traditional food crops, limiting calorie consumption from traditional crop to a mere 7% (Adhikari et al 2019).

**Table 1**. Consumption of millet in rural and urban populations

| Year | Share of millets in average per capita food consumption (%) | | |
|---|---|---|---|
| | Urban population | Rural Population | Overall population |
| 2015/16 | 4.1% | 5.7% | 5.1% |
| 2016/17 | 1.8% | 4.7% | 3.5% |

Source: Annual household surveys (CBS 2016, 2017)

Over the 32-year (1990/91 to 2021/22) dataset from Statistical Information on Nepalese agriculture by government of Nepal shows that the area under millet cultivation remained relatively consistent despite decrease in agricultural household percentages over the years. While the total millet production has showed an overall upward (**Figure 2**) trend but in a bigger picture looking at the production of other cereal crops, this is far from status for Nepal being independent on own cereal production. This rise, however, remains insufficient to attain increasing food and nutrition demand. Nepal's imports of millet alone have been substantial, reaching around 22,226 tonnes in the fiscal year 2021, marking an increase from 11,945 tonnes in 2017 (FAO 2023). Despite of an increase in production and import of millets, per capita consumption of millets is decreasing (**Table 1**). This scenario might be result of growing population, use of millets for livestock feed and brewery and changing consumers' dietary habits and social stigma attached with indigenous crops. Similarly, forecasts for 2030 suggest that the gap between domestic rice production and households' direct demand may range from 19% to 80%. This deficit in rice production is likely to persist despite efforts like increased irrigation and fertilizer supply (Prasad et al 2011). These estimates, however, do not account for climate extremes. Given this context, it becomes crucial for Nepal to diversify its cereal options, considering those that exhibit climate resilience and are well-suited to the geographical and socio-economic conditions. Future Smart Food crops like millets are a strong contender in this regard.

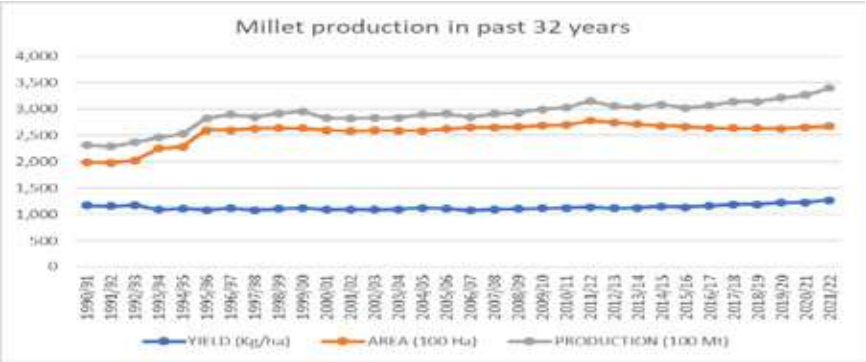


**Figure 2**. Millet production in past 32 years
MoAD 2015; MoALD 2023

Despite such significant importance of the crop, inadequate efforts are made to mainstream marginalized types of millets such as foxtail millet, proso millet and pearl millet in the food systems. Only data of a couple of types of millets such as finger millet is captured in national data, other millet varieties remain obscured.

Millets are typically found in cropping pattern of rainfed system (Paudel 2016) intercropped with other crop such as maize and legumes (Gauchan et al 2020), and compared to mono cropping the with traditionally practiced intercropping farmers are better off (Paudel 2016) However research on cropping practices of millets is very limited to finger millet with very few evidence agronomic practice of other millets.

## Major Constraints and Challenges to Millets and Other FSFs

It is clear that, millets in agri food system has been facing challenges. In this section we will discuss in detail the constraints that FSF such as millets has been facing in the contemporary condition. As, we are also exploring solutions and opportunity, we will later perform SWOT analysis based on the existing literature review of millet production and consumption in Nepal. The major constrains and challenges of millets in food system are as follow:

**Policy constraints:** Nepal's policies promoting millets utilization are well-intentioned yet face challenges hindering their effective implementation. The National Agriculture Policy (2061 BS) aims to enhance millet and minor cereal productivity via research, extension, and marketing. The policy underscores the importance of the millet's role in food security and marginalized farmers' livelihoods. Likewise, the Agriculture Development Strategy (2015-2035) designates millets as a priority crop for food security, nutrition, and climate resilience. This strategy envisions a 25% increase in millet cultivation area, 50% in production, and 20% in productivity by 2035. It emphasizes improved varieties, value addition, processing, and market linkages. Similarly, the National Nutrition Policy (2072 BS) seeks better nutritional status through diversified and nutritious food availability. The policy promotes millet and nutrient-rich crops in balanced diets and backs millet flour fortification with micronutrients. However, despite these well-defined policies, effective implementation has encountered challenges stemming from various factors:

- Inadequate coordination and collaboration among diverse stakeholders, including government bodies, research institutions, farmer groups, private sector entities, NGOs, and donors, have hindered progress. This lack of synergy can result in redundant efforts, conflicting strategies, and operational inefficiencies (Gyawali 2021).
- Rice and wheat are also more widely available and subsidized by the government in some countries, making them cheaper and more accessible than millet (WFP 2022).
- Insufficient resources, encompassing financial allocations, human capital, infrastructure, and technological capabilities, have constrained the efficacy and scope of policy implementation and monitoring efforts (Joshi and Joshi 2021).
- Political commitment and stability gaps have posed obstacles, impacting the sustainability and continuity of policy initiatives. Interference and corruption within political realms have further eroded transparency and accountability within the policy framework (Joshi and Joshi 2021)
- The absence of evidence-based research and rigorous analysis has led to suboptimal policy design and evaluation. Policy outcomes may suffer when decisions are based on assumptions, opinions, or personal interests rather than concrete data and information (Khadka et al 2016)
- The involvement and awareness of target groups, such as millet farmers and consumers, must be improved. It may diminish the acceptance and endorsement of policies and their potential outcomes. Sociocultural factors also play a role in shaping the preferences and behaviors of these target groups (Gyawali 2021)

**Market Constraints**: Millets farmers are grappling with challenges that hinder their ability to tap into markets and capitalize on value-addition opportunities effectively. One prominent issue is the need for access to markets and processing facilities, which directly impacts their ability to sell their produce at

reasonable prices. Unfortunately, Millets are often sold at lower prices or relegated to uses like home consumption or animal feed.

The lack of established standards, certifications, branding strategies, proper packaging, unambiguous labelling, efficient distribution networks, and promotional efforts all contribute to Millet's struggles in the market (Dos-Santos, 2020). Another crucial missing link is the scarcity of comprehensive market information and connections between various stakeholders in the millet supply chain. The disconnection between millet producers, processors, traders, and consumers exacerbates the challenges all parties involved face. Similarly, in market failures are also observed that has limit consumers from obtaining reliable information regarding traditional variety characteristics (Pallante et al 2016).

From the consumer's perspective, millets are often considered a poor people's crop or a famine food and has low social status compared to rice, wheat, and maize. Millet consumption is also declining due to changing food habits and urbanization (de Bruin et al 2021). There is a need for more awareness and promotion of millet as a healthy and nutritious food that can contribute to food security and malnutrition reduction. A recent study shows that the preference of tourists towards "*Dhido,"* a traditional dish made from millet flour, has increased its demand in recent years (Gyawali 2021).

**Technological constraints:** Millets are labor-intensive and drudgery-prone crop, requiring manual harvesting, threshing, dehulling, milling, and processing (Naik et al 2022). These operations are time-consuming and tedious, often resulting in low yields and quality losses. Manual processing exposes millet to contamination and spoilage by insects, rodents, fungi, and bacteria (Datta Mazumdar et al 2022). There is a lack of improved seed varieties, innovation, and land management practices to enhance millet productivity and quality. Millet is often grown in marginal lands with poor soil fertility, erratic rainfall, high temperatures, and pest and disease infestation. Millet farmers have limited access to quality seeds, fertilizers, pesticides, irrigation, mechanization, and extension services (Gyawali 2021). There is also a lack of appropriate technologies and equipment to reduce the labor and drudgery involved in millet processing and improve millet products' efficiency and hygiene (Shrestha et al 2020). Most of the existing millet processing technologies are based on traditional methods or adapted from wheat and rice milling technologies. These technologies are unsuitable for the small size, hard texture, and diverse shapes of millet grains. They often result in high energy consumption, low milling recovery, poor product quality, and high wastage (Joshi et al 2023).

A case study by Shrestha et al (2020) in Nepal examined the gender roles and drudgery of millet production and processing in the mid-hills. They found that women farmers were involved in almost all stages of millet production, such as land preparation, sowing, weeding, harvesting, threshing, dehulling, and milling. They also found that women farmers spent more time and energy than men farmers in these activities, especially in the post-harvest processing of millets. They reported that women farmers faced various challenges and drudgery in millet production and processing, such as physical fatigue, health problems, low productivity, low income, and lack of access to improved technologies and services. They suggested that empowering women farmers with improved technologies and skills could enhance their livelihoods and food security.

**Behavioral constraints:** Millet has a negative perception among many people as a crop only for festivals, rituals, or poor people (Kane-Potaka et al 2021). This is because marginalized communities traditionally consumed millet during famine or scarcity. Millets are also associated with specific religious or ethnic groups with lower social status in some societies (Prasad et. al 2010). Millet is often considered inferior to rice or wheat, which are seen as more modern, refined, and prestigious (Kane-Potaka et al 2021).

There is a lack of awareness and appreciation of the nutritional and health benefits of millets among consumers. Millets are rich in protein, fiber, minerals, antioxidants, and phytochemicals that can prevent or manage chronic diseases such as diabetes, obesity, cardiovascular problems, and cancer (Anitha et al 2021, Anitha et al 2021).

Another pressing challenge is disappearance of local culinary recipes and traditions that use millet as an ingredient. Due to urbanization, globalization, and changing lifestyles, many people have lost their connection with their ancestral food culture and heritage (Adhikari and Dangol 2013). Millet is often replaced by other cereals or processed foods that are more convenient, fast, and appealing (Hawkes et al 2017).

In following subsection, we perform a SWOT analysis based on the existing literature review on contemporary context of millet production and consumption in Nepal. (S: Strength, W: Weakness, O: Opportunities and T: Threats)

| | | Production/supply side | Consumption/demand side |
|---|---|---|---|
| **Socio-cultural** | S | • Socially acceptable in several ethnic communities of Nepal<br>• Traditional knowledge to cultivate in Nepal<br>• Linked with indigenous and local customs and norms | • Know how to consume in Nepalese rural households<br>• Millet has many benefits, such as being rich in protein, iron, calcium, zinc, and antioxidants, as well as being gluten-free, drought-tolerant, and adaptable to different soils and altitudes (Saxena et al 2018) (Kumar et al 2021)<br>• Linked with heritage of several ethnic and indigenous groups (Khanal 2022) |
| | W | • Requiring high labour input mainly during transplanting, weeding, harvesting, threshing, and grinding (Khadka et al 2016).<br>• Millets are more challenging to process initially compared to rice and wheat, with the most demanding processing required for minor millets<br>• (Joshi and Shrestha 2019, Pandey and Bolia 2023) | • Consider socio culturally inferior (Joshi and Shrestha 2019).<br>• Less palatable in traditional culinary practice (Pandey and Bolia 2023)<br>• Disappearance of local cuisine (Adhikari and Dangol 2013) |
| | O | | • Gluten free (Kumar et al 2021),<br>• Population growth (Li and Siddique 2018)<br>• Changing costumer attitude with rise in income and literacy (Thapa et al 2019) |
| | T | • Decreasing agricultural land (FRTC 2022) | • Compete with cheaper junk food option<br>• Consumer ignorance of nutritional value |
| **Economic** | S | • Low volume production in scattered area | • Relatively cheaper and healthier option of food |

| | | Production/supply side | Consumption/demand side |
|---|---|---|---|
| | W | • Lack of knowledge and investment for processing technology (Joshi et al 2020)<br>• High prices of hybrid varieties and poor economic conditions of small and marginal farmers is preventing them from using improved varieties.<br>• Lack of financial facilities (credit and insurance support) (Pandey 2022) | • Low economic evaluation of crops compared to its agroecosystem service.<br>• Farmers are not getting good prices for their products.<br>• Informal value chain<br>• Poor shelf life of millet flour (especially pearl millet) (Pandey and Bolia 2023b)<br>• Grain colour and astringent flavour (Pandey and Bolia 2023b)<br>• Technological interventions are required to handle some of the limitations of small millets like possibility of rancidity during storage (Pandey and Bolia 2023a)<br>• and presence of antinutrients like phytic acid [AP]<br>• Millet based enterprise lack proper linkages<br>• Market failures (Pallante et al 2016) |
| | O | • Low investment required for water and inputs as majorly grown in rainfed condition (Pandey and Bolia 2023)<br>• Rice and maize yield very susceptible to decline in climate change scenario (Nelson et al 2009). However millets are tolerant to stresses and require less investment in adaptation measures. | • Baby food ingredient<br>• Certification (mountain food, gluten free, vegan, organic)<br>• Use modern culinary science to make it more palatable and attract urban consumer<br>• UN international year of millets<br>• National Policy initiatives (NAP 2016, ADS 2072, NNP 2072)<br>• Public procurement<br>• Growing middleclass costumers<br>• Innovation in machineries (Pandey and Bolia 2023a) |
| | T | • Hybrid varieties of other cereal crops<br>• Farmers have limited access to quality seeds, fertilizers, pesticides, irrigation, mechanization, and extension services (Gyawali 2021)<br>• Lack of research in agronomic practices (Joshi and Shrestha 2019, Khadka et al 2016, MFSC 2014) | • Cheaper import from neighboring country |
| **Environmental** | S | • Fit easily into integrated practice (mix cropping)<br>• Intercropping system is profitable (Paudel 2016)<br>• Ability to tolerate and withstand stress. Less pressure to resources (ie, water)<br>• Low input requirement | • Local produce, low carbon footprint |
| | W | • - | • - |
| | O | • Agroecological agronomic package of practices | • Contributes to Agrobiodiversity conservation |
| | T | • - | • - |

## Towards a Framework for Sustainable Food Systems; Case of Millets

Based on the earlier section of SWOT analysis of consumption and production aspects of Millet, transformative initiatives are recommended

### Behavioral

**Linking habit, heritage, and health:** At the Himalayan Policy forum in May 2023, an example was shared regarding Natto, a fermented Japanese dish made from soybeans. It was explained how, despite its unpleasant taste, the Japanese actively seek it out for consumption no matter where they are in the world. It was emphasized that, similar to Natto, millets should be linked with habits established from early childhood, health and nutrition benefits, and the cultural heritage of the Nepalese. Such an approach will have a sustainable impact.

Millets can be linked with habit and health by encouraging their consumption among children through child health workers during health advice sessions to new parents, integrating it in school midday meal program and organizing dedicated campaigns. Millets could be further associated with heritage by acknowledging indigenous community for their contribution in preserving the traditional knowledge and considering traditional millet dishes as Nepalese delicacies in international platform.

### Technological

**Seed system and varietal development:** Seed system of all the millets are highly informal in Nepal (Baniya et al 1970; Gurung et al 2020) In a study on genotypes of finger millet, high level of diversity among the genotypes was observed for grain yield indicating their superior trait value suggesting for further research for breed improvement (Dhami et al 2018). Gurung et al (2020) suggest that to address limited knowledge and skill of farming communities in seed selection, processing and storage, strengthening of local seed system could be carried by our research and development work on the traditional mountain crops focusing on community seed banks and other community-based approaches to promote linkage with formal seed system. Similarly, to improve seed genotypes, Ghimire et al 2018 suggest that research institutes can employ an innovative method of using participatory diversity kits to promote farmer selection for immediate benefits.

**Agroecological farming approach:** As millets are neglected crops, they receive limited attention in research overall. To establish resilient millet farming system in Nepal, it is suggested to research in agroecological agronomic package of practices of millet farming and make technologies available throughout the nation.

**Agriculture mechanization:** One of the challenges in the millets value chain is post-harvest handling. Proper research is needed to develop suitable machinery that is compatible to local setting and can reduce drudgery associated with millet processing. Potential machinery includes the multi feed dehuller build by Tamil Nadu Agricultural University and Central Institute of Agricultural Engineering (Pandey and Bolia, 2023a), Finger Millet Harvesting Machine developed by Department of Automobile and Mechanical Engineering, Tribhuvan University Institute of Engineering, pedal millet thresher developed by Nepal Agricultural Research Council.

**Research in culinary science:** The limited consumption of millets in urban contexts often stems from a lack of recipes. Addressing this issue can involve research in culinary science, including the collection of traditional recipes and the study of fusion cuisine in gastronomy. Examples like the *Raithanee*[6] restaurant (Thomas Heaton 2019) demonstrate how this approach can be successful.



6 Raithaane is an urban restaurant situated in Kupondol, which serves food, derived from diverse ethnic groups of Nepal.

### Market

**Rebranding:** Millets have long been associated with lower socio-economic status, perpetuating a stigma around their consumption. To counter this, rebranding millets is recommended. Millets are gluten-free and vegan food options, and when grown using agroecological practices, they can be labelled as organic, fairtrade, and mountain products in Nepalese context. Leveraging these certifications and labels can help change the perception of millets among consumers.

**Business incubators for millet base enterprise:** Millets based products such as based baby food, lunch item, brewery, and other food item often rely on traditional knowledge for production and marketing. Incentives such like business fellowships for small and medium enterprises can enhance production quality and marketing capabilities, enabling these enterprises to reach a wider audience.

### Policy

**Financial investment**: Government should invest in research on varietal improvements, post-harvest processing technologies, appropriate machinery development, and market structure and infrastructure development of millet to create enabling environment for millet producers.

**Awareness raising campaign:** Public awareness campaigns to educate consumers, farmers, and food businesses about the economic, nutritional, and environmental advantages of millets. This will also contribute to counter market failures.

**Incentives:** Through government programs, incentives such as support price, subsidies, public procurement, and insurance should be provided to the millet producer to encourage production. Local government can play crucial role in this regard.

**Mainstreaming all the millets:** The Nepal Agriculture Research Council have identified 11 millet domesticated millet crops. However, there has been limited research on these millets concerning their traditional agronomic practices, varietal development, post-harvest handling, and food technology. Additionally, disaggregated data on production and yield for different types of millet is also lacking. To mainstream millets, relevant agencies must address these gaps.

## Concluding Remark for Solution

As a result of this research, several recommendations emerge to facilitate this transformation. Firstly, it is crucial to establish a strong connection between millets and elements of habit, heritage, and health to encourage behavioral shifts toward millets consumption. Moreover, technological advancements are important in enhancement of seed systems, varietal development, the adoption of agroecological farming practices, mechanization in agriculture, and increased research in culinary science should be prioritized.

In terms of market perspective, it is essential to embark on transformative initiatives such as rebranding millets through ethical and environmental certification and fostering business incubators for millets-based enterprises. Lastly and most importantly, policy intervention plays a critical role in addressing challenges costumer behavior, technology, market failures. It can create enabling environment for revival with approaches such as financial investments, awareness-raising campaigns, the provision of various incentives, and the mainstreaming of all types of millets.

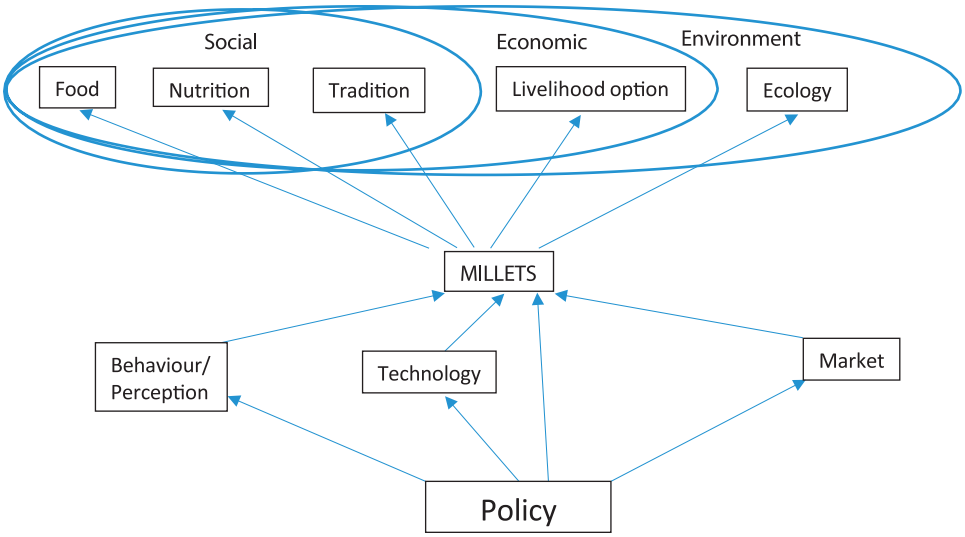


**Figure 3**: Factors influencing the integration of Millets into the food system and the impacts of Millet- based food systems.

By implementing these multifaceted recommendations drawn via comprehensive strategic way, we can pave the way for a more sustainable and inclusive food system that harnesses the potential of millets and other FSF to address pressing societal, economic, and environmental challenges.

## Acknowledgements

This research was carried out under the financial support of GRAPE project. We are very grateful to the GRAPE project and ICIMOD for their support and guidance.

## References

Adhikari BM and K Dangol. 2013. Study on Traditional Technology of Nepalese Fried Snack Woh. Journal of Food Science and Technology Nepal, 8, 35–39. https://doi.org/10.3126/JFSTN.V8I0.11747

Adhikari L, A Hussain and G Rasul. 2017. Tapping the Potential of Neglected and Underutilized Food Crops for Sustainable Nutrition Security in the Mountains of Pakistan and Nepal. Sustainability, 9(2), 291. https://doi.org/10.3390/su9020291

Adhikari L, S Tuladhar, A Hussain and K Aryal. 2019. Are traditional food crops really "future smart foods?" a sustainability perspective. Sustainability (Switzerland), 11(19). https://doi.org/10.3390/su11195236

Anitha S, RBotha, J Kane-Potaka, DGivens, A Rajendran, TWTsusaka and RK Bhandari. 2021. Can Millet Consumption Help Manage Hyperlipidemia and Obesity?: A Systematic Review and Meta- Analysis. Frontiers in Nutrition, 8, 700778. https://doi.org/10.3389/FNUT.2021.700778/BIBTEX

Anitha S, J Kane-Potaka,TW Tsusaka, R Botha, A Rajendran, DI Givens, DJ Parasannanavar, K Subramaniam KDV Prasad, M Vetriventhan and RK Bhandari. 2021. A Systematic Review and Meta-Analysis of the Potential of Millets for Managing and Reducing the Risk of Developing Diabetes Mellitus. Frontiers in Nutrition, 8, 687428. https://doi.org/10.3389/FNUT.2021.687428/BIBTEX

Baniya BK, RK Tiwari, P Chaudhary, SK Shrestha, and PR Tiwari. 1970. Planting Materials Seed Systems of Finger Millet, Rice and Taro in Jumla, Kaski and Bara Districts of Nepal. Nepal Agriculture Research Journal, 6, 10–22. https://doi.org/10.3126/narj.v6i0.3343

CBS. 2016. Annual Household Survey 2015/16. CBS. (2017). Annual Household Survey 2016/17.

Datta Mazumdar S, D Priyanka and Y Akhila. 2022. Emerging Technologies in Millet Processing. Handbook of Millets - Processing, Quality, and Nutrition Status, 231–263. https://doi.org/10.1007/978-981-16-7224-8_11/COVER

De Bruin S, J Dengerink, and J Van Vliet. 2021. Urbanisation as driver of food system transformation and opportunities for rural livelihoods. Food Security, 13(4), 781–798. https://doi.org/10.1007/s12571-021-01182-8

Dhami NB, M Kandel, SB Gurung and J Shrestha. 2018.. AGRONOMIC PERFORMANCE AND CORRELATION ANALYSIS OF FINGER MILLET GENOTYPES (ELUSINE COROCANA L.). Malaysian Journal of Sustainable Agriculture, 2(2), 16–18. https://doi.org/10.26480/mjsa.02.2018.16.18

Dos-Santos MJPL. 2020. Value Addition of Agricultural Production to Meet the Sustainable Development Goals. 1–8. https://doi.org/10.1007/978-3-319-69626-3_55-1

FAO. 2022. Repurposing food and agricultural policies to make healthy diets more affordable. In The State of Food Security and Nutrition in the World 2022.

FAO. 2023. Food and Agriculture Organization of the United Nations. FAOSTAT Statistical Database. Rome. Extracted from: https://www.fao.org/faostat/en/#data/TCL

FRTC. 2022. National Land Cover Monitoring System of Nepal. Forest Research and Training Centre (FRTC)

Gauchan D, B Joshi, B Bhandari, H Manandhar and D Jarvis. 2020. Traditional crop biodiversity for mountain food and nutrition security in Nepal : tools and research results of the UNEP GEF local crop project, Nepal. The Alliance of Bioversity International and CIAT, NAGRC, LI-BIRD.

Ghimire KH, BK Joshi, R Dhaka and BR Sthapit .2018. Diversity in proso millet (Panicum miliaceum L landraces collected from Himalayan mountains of Nepal. Genetic Resources and Crop Evolution, 65(2), 503–512. https://doi.org/10.1007/s10722-017-0548-7

Gurung R, N Pudasaini, S Sthapit, E Palikhey, AR Adhikari, and D Gauchan. 2020. Seed System of Traditional Crops in the Mountains of Nepal.

Gyawali P. 2021. Production Trend, Constraints, and Strategies for Millet Cultivation in Nepal: A Study from Review Perspective. International Journal of Agricultural and Applied Sciences, 2(1), 30–40. https://doi.org/10.52804/ijaas2021.213

Hawkes Harris J, SC Gillespie. 2017. Title: Urbanization and the Nutrition Transition. 4, 34–41. https://doi.org/10.2499/9780896292529_04

Heaton T. 2019. This restaurant is challenging the notion that Nepali food is just momos and dal bhat. The Kathmandu Post. Published at: April 1, 2019.
https://kathmandupost.com/food/2019/04/01/one-patan-restaurant-is-challenging-the-notion-that- nepali-food-is-just-momos-and-dal-bhat

Hussain A and FM Qamar. 2020. Dual challenge of climate change and agrobiodiversity loss in mountain food systems in the Hindu-Kush Himalaya. One Earth, 3(5), pp.539-542.

Joshi BK. (2022). Millets in Nepal: For human, livestock and environment Background. Nepal Agricultural Research Centre

Joshi BK and R Shrestha. 2019. Nepal. In X. Li and K. H. M. Siddique (Eds.), Future Smart Food - Rediscovering Hidden Treasures of Neglected and Underutilized Species for Zero Hunger in Asia (pp. 161–178). FAO.

Joshi BK , R Shrestha, D Gauchan and A Shrestha. 2020. Neglected, underutilized, and future smart crop species in Nepal. Journal of Crop Improvement, 34(3), 291–313. https://doi.org/10.1080/15427528.2019.1703230

Joshi GR and B Joshi. 2021. Agricultural and Natural Resources Policies in Nepal: A Review of Formulation and Implementation Processes and Issues. Nepal Public Policy Review, 212–227. https://doi.org/10.3126/NPPR.V1I1.43459

Joshi TJ, SM Singh and PS Rao. 2023. Novel thermal and non-thermal millet processing technologies: advances and research trends. European Food Research and Technology, 249(5), 1149– 1160. https://doi.org/10.1007/S00217-023-04227-8/METRICS

Kane-Potaka J, S Anitha, TW Tsusaka, R Botha, M Budumuru, S Upadhyay, P Kumar,K Mallesh, R Hunasgi,AK Jalagam, and S Nedumaran. 2021. Assessing Millets and Sorghum Consumption Behavior in Urban India: A Large-Scale Survey. Frontiers in Sustainable Food Systems, 5, 680777. https://doi.org/10.3389/FSUFS.2021.680777/BIBTEX

Khadka K, A Shrestha A, R Devkota and D Upadhaya. 2016. Constraints and Opportunities for Promotion of Finger Millet in Nepal. LIBIRD. https://doi.org/10.13140/RG.2.2.13997.69606

Khanal P. 2022. Timmur: stories and flavours from Nepal. Fine Print.

Kumar A, V Tomer, A Kaur, V Kumar, K Gupta,. 2018. Millets: a solution to agrarian and nutritional challenges. Agriculture and food security, 7(1), 31.

Kumar A, MK Tripathi, V Singh, S Pandey, V Kumar, RS Jadam, and D Mohapatra. 2021. Nutritional Composition of Millets. In Millets and Millet Technology (pp. 1–438). Springer Singapore. https://doi.org/10.1007/978-981-16-0676-2

Li, X and KHM Siddique. 2018. FUTURE SMART FOOD Rediscovering hidden treasures of neglected and underutilized species for Zero Hunger in Asia. www.fao.org/publications

Li, X., M EL Solh and KHM Siddique. 2019. MOUNTAIN AGRICULTURE Opportunities for harnessing Zero Hunger in Asia.

Mal B, S Padulosi and S Bala Ravi editors. 2010. Minor Millets in South Asia: Learnings from IFAD- NUS Project in India and Nepal. Bioversity International, Maccarese, Rome, Italy and the M.S. Swaminathan Research Foundation, Chennai, India. 185 p.

MFSC. 2014. Nepal National Biodiversity Strategy and Action Plan 2014–2020. In Ministry of Forests and Soil Conservation (MFSC), Government of Nepal.

MoAD. 2015. Statistical Information on Nepalese Agriculture 2071-72. MoALD. (2023). Statistical Information on Nepalese Agriculture 2078-79.

Naik M, N Modupalli, CK Sunil, A Rawson, and V Natarajan. 2022. Major Millet Processing. Handbook of Millets - Processing, Quality, and Nutrition Status, 63–80. https://doi.org/10.1007/978- 981-16-7224-8_4/COVER

Nelson GC, MW Rosegrant, J Koo, R Robertson, T Sulser, T Zhu, C Ringler,S Msangi, A Palazzo, M Batka, M Magalhaes, R Valmonte-Santos, M Ewing, D Lee. 2009. Climate change impact on agriculture and costs of adaptation. In: Food Policy Report. International Food Policy Research Institute (IFPRI), Washington D.C, 19.

Pallante G, GD Adam, S Sthapit. 2016. Assessing the potential for niche market development to contribute to farmers' livelihoods and agrobiodiversity conservation: Insights from the finger millet case study in Nepal. Ecological Economics (Vol 130), 92-105. https://doi.org/10.1016/j.ecolecon.2016.06.017.

Pandey A. 2022. Credit and Financial Access in Nepalese Agriculture: Prospects and Challenges. The Journal of Agriculture and Environment 23.

Pandey A, and NB Bolia. 2023a. Millet value chain revolution for sustainability: A proposal for India. Socio-Economic Planning Sciences, 87. https://doi.org/10.1016/j.seps.2023.101592

Pandey A, and NB Bolia. 2023b. Nutritional Composition of Millets. In Socio-Economic Planning Sciences (Vol. 87). Elsevier Ltd. https://doi.org/10.1016/j.seps.2023.101592

Paudel MN. 2016. Multiple Cropping for Raising Productivity and Farm Income of Small Farmers. Journal of Nepal Agricultural Research Council, 2, 37–45. https://doi.org/10.3126/jnarc.v2i0.16120

Prasad SK, H Pullabhotla and A Ganesh-Kumar. 2011. Discussion paper: Supply and Demand for Cereals in Nepal, 2010-2030.

Prasad RC, RP Upreti, S Thapa, LB Jirel, PR Shakya, and DN Mandal .2010. In Mal, B., Padulosi, S., and Bala Ravi, S., (Eds.), Minor Millets in South Asia: Learnings from IFAD-NUS Project in India and Nepal. Bioversity International, Maccarese, Rome, Italy and the M.S. Swaminathan Research Foundation, Chennai, India.

Saxena R, SK Vanga, J Wang, V Orsat and V Raghavan. 2018. Millets for Food Security in the Context of Climate Change: A Review. Sustainability 10, no. 7: 2228. https://doi.org/10.3390/su10072228

Shrestha J, R Shrestha, BK Joshi and S Subedi. 2020. FUTURE SMART FOOD CROPS IN NEPAL: A NECESSITY FOR FUTURE FOOD AND NUTRITIONAL SECURITY. Natural Resources and Sustainable Development, 10(1), 46–56. https://doi.org/10.31924/nrsd.v10i1.043

Thapa G, A Kumar and PK Joshi. 2019. Agricultural Transformation in Nepal Trends, Prospects, and Policy Options.

UNRIC. 2023. Millets – good for people, the environment, and farmers. United Nation Regional Information Centre.

World Food Programme. 2022. The State of Food Security and Nutrition in the World 2022.

Repurposing food and agricultural policies to make healthy diets. Food and Agriculture Organization of the United Nations.

***


**National Agriculture Geneteic Resources Center (Genebank)**
NAGRC-NARC, PO Box 3055, Lalitpur-15, Nepal
Email: genebank@narc.gov.np, narc.genebank@gmail.com
Tel: 01-527 5131
URL: https://genebank.narc.gov.np/

**Center for Crop Development and Agrobiodiversity Conservation (CCDABC)**
DoA, Shri-Mahal, Lalitpur, Nepal
Email: cdabc2018@gmail.com
Tel: 01 555 0226
URL: www.doacrcp.gov.np

**Food and Agriculture Organization of the United Nations (FAO)**
UN House Pulchowk, Lalitpur, Nepal
Email: fao-np@fao.org
Tel: 01-4290000
URL: https://www.fao.org/nepal/en/

9 789937 149952