Meeting the Growing Demand for Nutri-Cereals: A Supply Assessment for Maharashtra, India

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ABSTRACT

Background: Millets offer solutions for multiple challenges, including malnutrition, food insecurity, resource scarcity, agricultural production risks due to climate change and lifestyle-related health problems. Hence, increasing millet production and consumption contributes to achieving the United Nations' Sustainable Development Goals (SDGs) 2, 3, 12 and 13. The Government of India is actively promoting these crops to benefit both people and the planet. In recent years, there has been a growing awareness among urban populations about the nutritional benefits of millet. However, their supply has dwindled over the years due to a decrease in the land area dedicated to millet cultivation, which high-value commercial crops have replaced. If this trend continues, it could lead to a potential shortage of millets within the country.

Methods: In this study, the anticipation demand and supply of millets in the Maharashtra state of India was projected by analyzing consumer expenditure data from the National Sample Survey Organization (NSSO) for the year 2011-12. Demand estimation was conducted through three distinct methodologies; static projections, normative benchmarks and behavioristic- Quadratic Almost Ideal Demand System (QuAIDS) model allowing for comprehensive insights into consumption patterns and elasticity responses.

Result: The projected demand for millets by 2036 is estimated at 3.90 million tons, while the supply is anticipated to be 0.76 million tons, resulting in a deficit of -3.14 million tonnes. If the current trends in cultivated area and crop yield persist, a substantial net deficit will be observed across all millet varieties included in the study. To mitigate this shortfall, strategic enhancing yield potential through initiatives as distributing high-quality seeds, incorporating biofortified varieties, promoting awareness, implementing price incentives and providing facilities for processing.

Key words: Consumer expenditure, Demand, Millets, Projection, Supply.

INTRODUCTION

Millets have been an integral component of the human diets for nearly 7,000 years, playing a crucial role in developing multi-crop agriculture and settled farming societies (Cherfas, 2015). Cultivating millets can improve food security for marginal farmers, especially in drought-affected areas, making them a viable option in the face of climate change (Prema and Ramachandran, 2023). Major millets include sorghum, pearl millet and finger millet, while minor millets consist of foxtail millet, proso millet, kodo millet, barnyard millet, little millet, brown top millet, sea millet, teff millet and Sonia millet (ASSOCHAM, 2022). Worldwide production stands at 86.3 million tons (MT) across 13.8 million hectares (Mha). India is a significant producer of millet, accounting for 20% of global production and 80% of production in Asia. The average millet yield globally is 1229 kg/ha, while India's average productivity is slightly higher at 1239 kg/ha (FAO, 2021). According to Kane-Potaka *et al*. (2021), the highest consumption is observed in Bengaluru (71.2%), followed by Chennai (57.6%), Hyderabad (56.1%), Mumbai (52.9%), Kolkata (52.3%), Delhi (41.9%)and Ahmedabad (37.7%). Approximately 49.6% of Indians consume millet at least once weekly, whereas 34.9% rarely or never include it in their diet. Daily millet consumption averages at 14.8 grams per day (g/day) in rural areas and 7.33 g/day in urban areas (Government of India, 2012). Monthly per capita millet consumption in urban households (2.29 kg) is notably higher than in rural areas (1.83 kg) (Vahini *et al*., 2023). Reddy *et al.* (2013) studied the utilization pattern, demand and supply of pearl millet grain and fodder in western India. Their findings revealed a present shortage of grain production, leading to higher prices. However, they projected a potential 5% surplus by 2020 if the region maintains its high production growth trend of 4.22% per annum. This highlighted the positive outlook for the future supply of pearl millet in Western India. Sharma *et al.* (2013) conducted a study on demand and supply projections for pearl millet in Rajasthan. They found that the projected

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supply and demand (food) for pearl millet in 2025 is 7759 thousand tonnes and 2613 thousand tonnes in Rajasthan, respectively. Parthasarathy Rao and Basavaraj (2015) highlighted a shift in millet usage in Asia from staple foods to alternative purposes, such as animal feed and alcohol production, driven by increasing incomes, urbanization and policies favoring rice and wheat. More than 50% of millet production is currently allocated for non-staple uses, with a rising demand for millet-based processed foods among urban consumers in India. Malathi *et al.* (2016) conducted a study on the growth pattern of millets in India. They found that millet cultivation has significantly declined due to government policies favouring other crops, such as cereals and oilseeds. Despite this, there was a 47.41% increase in finger millet production, along with a 147.49% rise in crop yields. Pearl mill*et al*so showed improvements, with a 247.48% increase in productivity and a 255.61% increase in crop yield. Sreekala (2023) reported a likely excess supply of bajra and minor millets in upcoming years, contrasted with anticipated shortages in jowar and ragi. This projection underscores the need for targeted policy measures to ensure a balanced supply across millet varieties. Deevi *et al*. (2024) predicted a rise in global millet demand from 48.5 to 66.5 million tons between 2030 and 2050, with an expected supply deficit in Asia, highlighting the importance of trade to bridge the demand-supply gap. In India, various challenges affect the availability and accessibility of millets. Despite their many nutritional benefits and suitability for different agro-climatic conditions, millets often have limited demand and insufficient market infrastructure. This leads to reduced cultivation and supply (Kumar *et al.,* 2018), creating a significant gap between the potential need for millets and their availability in the market (Melinda *et al.,* 2016). Addressing this issue is crucial for making informed decisions, formulating policies and allocating resources to ensure food security and meet the future nutritional needs of the population. Therefore, the present study focuses on projecting the demand and supply of millet in Maharashtra state, one of India's leading millet-producing and consuming states.

MATERIALS AND METHODS

The study uses secondary data from published sources. Maharashtra state was purposively selected for the study because of the presence of a considerable area, the production of millet and an adequate sample size of consumers. Data related to consumer expenditure on food and non-food items were collected from the National Sample Survey Organization (NSSO), Ministry of Statistics and Programme Implementation, Government of India. The data pertains to the 68th round of 2011-12 year (Government of India, 2012). The total number of households surveyed in Maharashtra State was 8043, of which 4032 were from rural areas and 4011 were from urban areas. The Maharashtra State's population projection data were taken from the National Commission of Population, 2020. The urban area population is increasing at a rate of 1.34%; by 2036, the urban population of Maharashtra will reach 71.46 million, but the rural population is growing at a decreasing rate of 0.23% only. By 2036, the rural population will reach 65.52 million and the state's total population will be 136.98 million, increasing by 0.77 % (Government of India, 2020). The population projections are available up to 2036 only; hence, the demand and supply estimations are computed until 2036. The state's per capita income growth rate is 7.68 per cent from 2011 to 2019 (Government of Maharashtra, 2020).

Statistical analysis

Demand projection

The following three approaches were used to estimate demand (NITI Aayog, 2018).

1. Static approach: Demand is projected by multiplying the projected population with the consumption parameters of the base year, assuming the short-term static consumption behavior.

Demand projection =
Projected population in ith year $\times$ Per capita consumption

2. Normative approach: Demand is estimated by multiplying the projected population with the RDA of millets given by the National Institute of Nutrition (ICMR-NIN), Hyderabad, India.

Demand projection = Projected population in ith year $\times$ RDA

The ICMR-NIN, RDA value of millets is 100 g/day/capita (Government of India, 2011; Shenai, 2022).

3. Behavioral approach: In this approach, demand is estimated based on population growth and changing consumer behavior based on changing per capita income in a growing economy, measured in terms of consumption/ expenditure elasticities. There are different behavioral approaches, such as Translog systems (Christensen *et al.,* 1975), Almost Ideal Demand System (AIDS) (Deaton and Muellbaur, 1980; Yeong-Sheng and Radam, 2011; Musyoka *et al.,* 2010) and Quadratic Almost Ideal Demand Systems (QuAIDS) (Banks *et al.,* 1997).

The QuAIDS model was used in the present study, an extension of the almost ideal demand system developed by James Banks, Richard Blundell and Arthur Lewbel. It considers the existence of a non-linear engel curve that is not expressed in the standard almost ideal demand system (Barman and Toor, 2017; Khanal *et al.,* 2015; Kumar *et al.,* 2021; Mittal, 2010; Qi *et al.,* 2015). QuAIDS will be approached in the multi-stage budget frame as follows:

Multi-stage budgeting framework

Stage 1: FD= f (PF, PNF, Y, Y^2, Z)

FD- Per capita food expenditure
PF- Geometric mean of food prices.

$$PF = \sum W_j \ln P_j$$

W_j= Share of the jth commodity in food expenditure.
P_j= Price of jth commodity.

PNF- Per capita non-food expenditure.
Y- Income variable capturing linear expenditure.
Y^2- Income variable capturing non-linear expenditure.
Z- Dummy variable representing demographic factors affecting consumption, such as household size, rural and urban.

In stage 1, per capita expenditure on food will be taken as a function of the geometric mean of food prices. Food items included are cereals, pulses, millet, milk, sugar, salt, oil, vegetables, MFE (meat, fish, egg), fruits, spices, beverages and packed, processed products.

Stage 2: FM = f (P, FD, FD^2, Z)

FM- Per capita expenditure on millets.
P- Vector representing the prices of various food commodities.
FD- Instrumental variable calculated in stage 1.
FD^2- Indicates the non-linear forms of FD.

In stage 2, millet's expenditure (FM) is specified. Per capita millets expenditure is the function of different types of substitute foods and complementary foods.

Stage 3: W_i = f (PF, FM/P*, FM^2/P*, Z)

In stage 3, the QuAIDS model for specific millet types is specified. The budget share of each millet type (Wi) is the function of millet prices and expenditures. The above equation gives QuAIDS model:

P* stone price index (log P* = $\sum W_j \log P_j$)

The uncompensated price elasticities, in which both incomes, as well as substitution effects, are considered, are estimated by using the results of the QuAIDS model:

$$\varphi_{ij} = (W_i / b_i) - \{c_{1i} + 2c_{2i} \ln (FM)\} - k_{ij}$$

K_{ij} = Knonecker delta.
K_{ij} = 1 for its own price elasticity and it is zero for cross-price elasticity.
W_i = Consumption share of i^{th} food items and b_i and c_i are the parameters that the QuAIDS model estimates.

The following equation gives the food expenditure elasticity of individual food items:

$$\eta i = (c_{1i} + 2c_{2i} \ln (FM / W_i) + 1)$$

The income elasticity for a specific food item is computed by using food expenditure elasticity η^{FD} and millet expenditure elasticity $\eta^{FM,}$ which is already estimated in earlier.

Income elasticity for specific food item: $\eta^{yi} = (\eta^{FD})(\eta^{FM})(\eta^{i})$

Demand projection formula: $D_t = D_0 * N_t (1 + y*e)$

D_t = Household demand of a commodity in year t.
D_o- Per capita demand of the commodities in the base year.
y- Growth in per capita income.
e- Expenditure elasticity of demand for the commodity.
N_t - Projected population in year t.

Fig 1 shows a multi-stage budgeting framework demand model Kumar *et al.* (2021); Sivaramane *et al.* (2009) for millets.

Supply projection

Supply was projected using compound annual growth rates (CAGR) of production for the last ten years (Sreekala *et al.,* 2023; Shirish and Singh, 2013); the base year is 2011-12.

$$Y = ab^t$$

Y = Year-wise production of millets.
a = Constant.
b = Trend coefficient.
t = Time.
CAGR (%) = (Antilog of b - 1) ×100

RESULTS AND DISCUSSION

Consumption pattern of millets in Maharashtra

The millet consumption in Maharashtra's rural and urban area is given in Table 1. Sorghum consumption by rural residents is 15.60 kg per capita annually. Whereas urban residents consumption is 5.88 kg per capita annually, resulting in a state wide per capita consumption of 21.48 kg per annum. Following sorghum, pearl millet ranks second in consumption, with rural and urban per capita consumption at 6.77 kg and 2.09 kg per year, respectively, totaling 8.86 kg per capita annually. Finger millet has a lower consumption rate, with rural areas consuming 2.44 kg per capita annually and urban areas 0.26 kg per capita, leading to a total consumption of 2.7 kg per capita per year. Small millet consumption is significantly lower, with rural consumption at 1.00 kg per capita annually and urban consumption at 0.36 kg per capita, resulting in a statewide total of 1.36 kg per capita per year. Overall, millet consumption in urban areas is notably lower than in rural areas, based on the 2011-12 base year data. Sorghum consumption in rural areas was approximately 61%, followed by pearl millet (26%), finger millet (9%) and small millet (4%). In the case of urban areas, sorghum consumption was 69%, followed by pearl millet (24%), small millet (4%) and finger millet (3%). The consumption patterns are on par with those of Gali and Rao (2012), who estimated the consumption pattern of sorghum in different regions of India using 2004-05 consumer expenditure data.

Demand projection by static approach

In the static approach, the base year (2011-12) demand projections for sorghum, pearl millet, finger millet and minor millets in rural areas are 0.96, 0.42, 0.15 and 0.06 MT, respectively, in the case of the urban regions the demand for the same, is 0.30, 0.11, 0.01 and 0.02 MT respectively, total demand is 1.26, 0.52, 0.16 and 0.08 MT and all millets together base year demand is 2.02 MT, but the actual production in 2011-12 are 2.54, 0.80, 0.13 and 0.03 MT and total millets productions are 3.5 MT (Government of India, 2021) which is more than that of estimated household demand, beyond household consumption, the surplus millet produce will go for seed purpose, animal feed, industrial applications and wastage (SWFI) also. There is a slight increase in demand for sorghum and pearl millet in urban areas, *i.e*., 0.42 and 0.15 MT, respectively, which

declined in rural areas and the projected demand was steady in the case of finger millet in rural (0.16 MT) and urban (0.02 MT) areas. In the case of minor millets also, demand is steady in rural (0.07 MT) and urban (0.03 MT) up to 2036; the details are shown in (Fig 2).

The static approach predicts increased household demand for sorghum from 1.26 MT (2011) to 1.44 MT (2036). For pearl millet, the projection increased from 0.52 MT (2011) to 0.59 MT (2036). The growth in demand for finger millet and minor millet is comparatively lower, resulting in

Table 1: Consumption pattern of millets in Maharashtra (kg/capita/annum) 2011-12.

Items	Rural	Urban	Rural + Urban
Sorghum	15.60	5.88	21.48
Pearl millet	6.77	2.09	8.86
Finger millet	2.44	0.26	2.70
Small millets	1.00	0.36	1.36

Data Source: NSSO, Government of India.

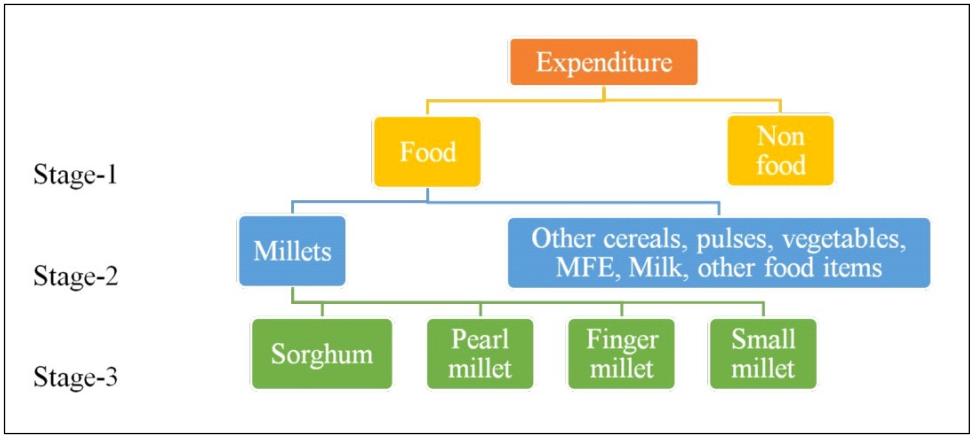


Fig 1: Multi-stage budgeting flow diagram.

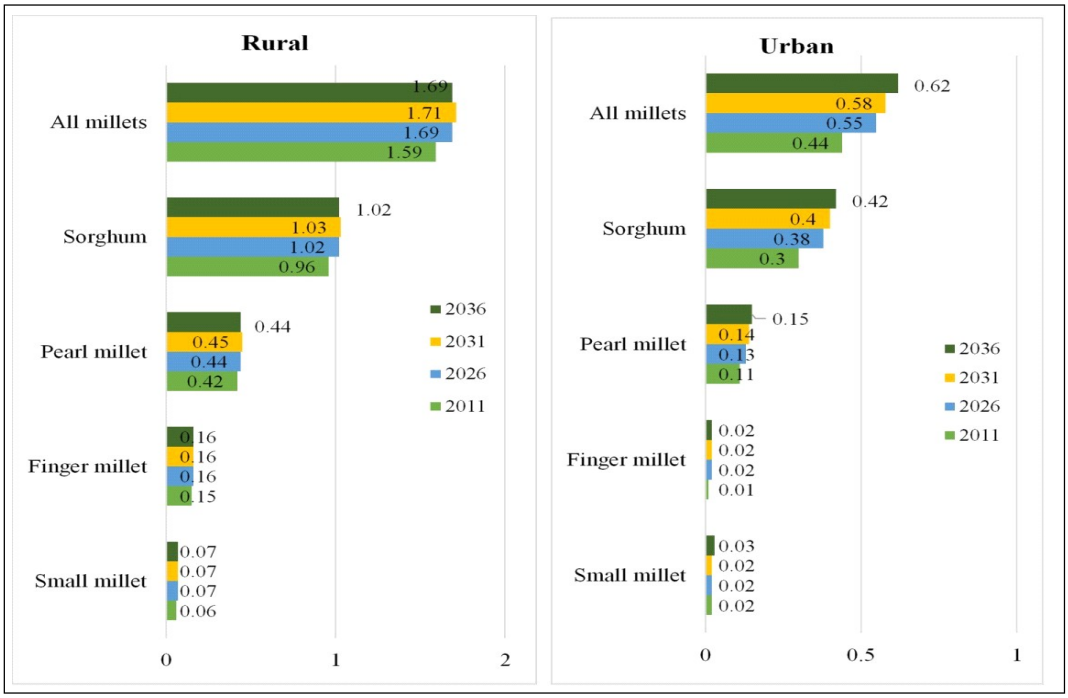


Fig 2: Household demand projection of millets in rural and urban areas using static approach (Million tons).

an overall increase in millet demand from 2.02 MT (2011) to 2.3 MT (2036).

Demand projection by normative approach

As per the normative approach, the household demand for millets in rural areas of Maharashtra is projected to be 2.39 MT, while urban areas are expected to reach 2.61 MT, resulting in a total demand of 5.00 MT by 2036. The demand in rural areas has slightly declined from 2.4 MT in 2031 to 2.39 MT in 2036 due to a decrease in the estimated population. However, the actual millet production was only 3.5 MT in 2011-12, which falls short of meeting the requirements of SFWI-the estimations given in (Fig 3).

The ICMR-National Institute of Nutrition (NIN) has recommended a daily intake of 100 grams of millet as part of the Recommended Dietary Allowances (RDA). However, in rural areas of Maharashtra, the actual consumption quantity is 71.66 g/day, with sorghum, pearl millet and minor millets contributing 43.33 g, 18.8 g and 9.53 g, respectively. In urban areas, the consumption quantities are 16.33 g,

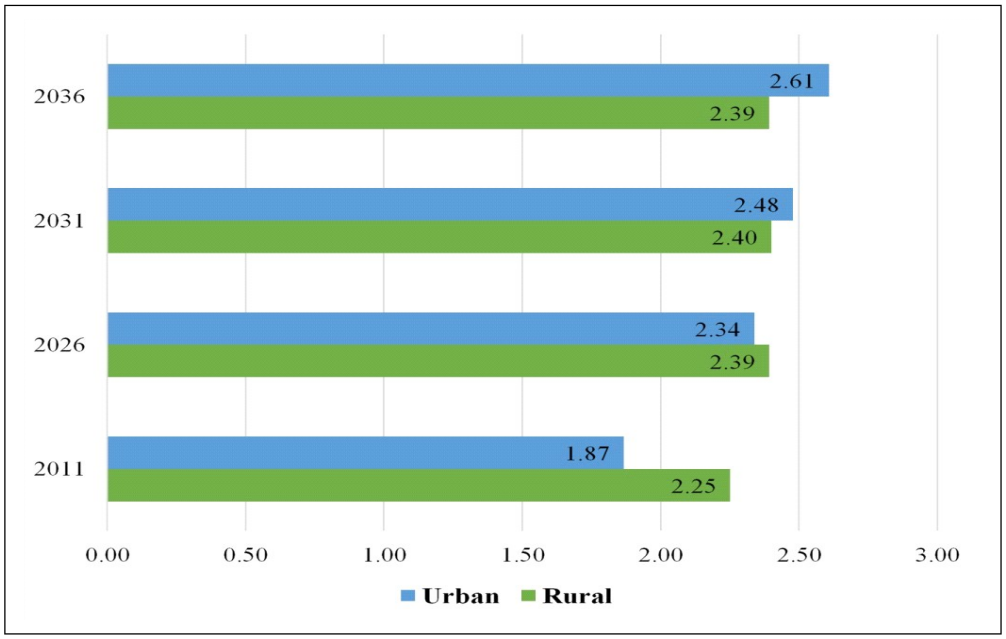


Fig 3: Household demand projection of millets - Normative approach (Million tons).

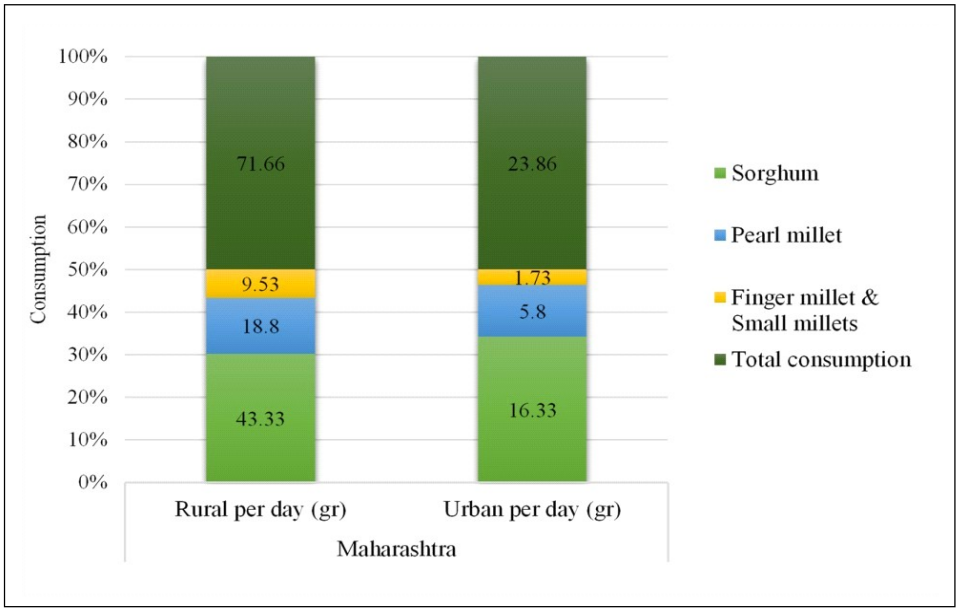


Fig 4: Per day consumption of millets in Maharashtra state (Million tons). Source: NSSO, Government of India.

5.8 g and 1.73 g, respectively, resulting in a total consumption of 23.86 g/day, which falls significantly below the RDA value. The details are depicted in (Fig 4).

Demand projection by behavioristic approach

The QuAIDS model was utilised to estimate price and income elasticities for millets in rural and urban areas. As presented in Table 2, the price elasticities for millets ranged from -0.877 to -1.024, indicating a relatively elastic demand. This means that a one per cent increase in the price of sorghum would decrease demand by approximately 1.0227 per cent. Similarly, the price elasticities of all other millets were also negative, indicating their relative elasticity. Regarding income elasticities, the values ranged from 0.0003 to 0.0021, indicating an inelastic nature which suggests that a one per cent increase in income would lead to a minimal increase in the demand for sorghum, approximately 0.0021 per cent. In contrast, the income elasticities for other millets were close to zero. These findings align with the results of Kumar *et al.* (2009) when estimating expenditure elasticities for coarse cereals using 2004-05 consumer expenditure data.

According to the behaviouristic approach, the demand for millets is projected to increase in rural areas to 2.27 MT and in urban areas to 0.86 MT, resulting in a total demand of 3.13 MT by 2036. The demand for finger and minor millet remains stable in rural and urban areas, while a slight increase in demand (from 0.61 MT to 0.64 MT) is observed for pearl millet. The demand for sorghum is expected to rise from 1.81 MT to 2.20 MT between 2026 and 2036. Overall, the demand for millets is projected to increase from 2.05 MT in 2011 to 3.13 MT in 2036. Rural and urban areas-wise details are depicted in (Fig 5).

According to the official estimates of the 10th and 11th five-year plans of the Government of India, the SFWI (Seed, Feed, Wastage and Industry) requirement was set at 12.5% of the gross output of all food grains (NITI Aayog, 2018). By adding this 12.5% to the household demand, we can calculate the total demand for millets, as presented in (Table 3). Hence by 2036, both direct (household) and indirect (SFWI) demand for millets will be 3.90 MT in Maharashtra state.

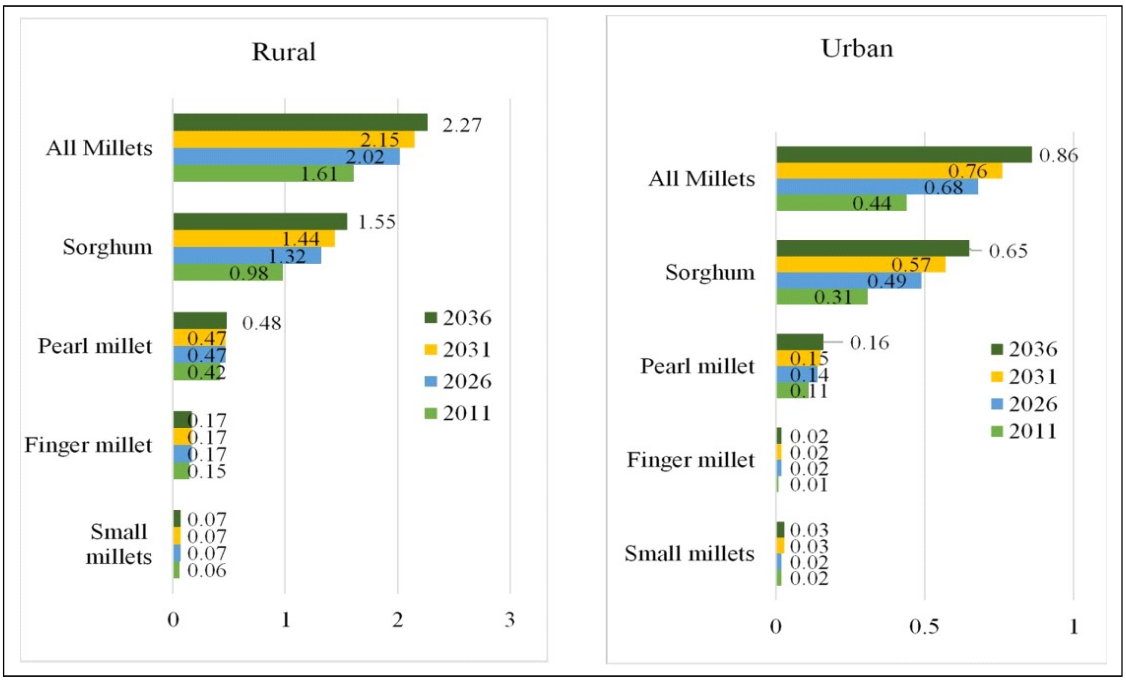


Fig 5: Household demand projection of millets in rural and urban areas using a behaviouristic approach (Million tons).

Table 2: Price and income elasticities of millets in Maharashtra.

Crop	Rural		Urban		Rural + Urban	
	Price elasticity	Income elasticity	Price elasticity	Income elasticity	Price elasticity	Income elasticity
Sorghum	-1.0272	0.0021	-1.0182	0.0022	-1.0227	0.0021
Pearl millet	-1.0327	0.0004	-1.0161	0.0004	-1.0244	0.0004
Finger millet	-0.9058	0.0003	-0.7591	0.0003	-0.8775	0.0003
Small millets	-0.9980	0.0006	-0.9966	0.0006	-0.9976	0.0006

Table 3: Total demand projections of millets in Maharashtra (MT).

Year	Static	Normative	Behaviouristic	Average
2011	2.27	4.64	2.31	3.07
2026	2.53	5.32	3.04	3.62
2031	2.58	5.49	3.29	3.78
2036	2.59	5.63	3.52	3.90

Table 4: Total supply projections of millets in Maharashtra (MT).

Year	Sorghum	Pearl millet	Finger millet	Small millets	Total
2011	2.54	0.80	0.13	0.03	3.50
2026	1.79	0.69	0.09	0.02	2.59
2031	1.04	0.57	0.06	0.01	1.67
2036	0.28	0.46	0.02	0.00	0.76

Table 5: Demand and supply gap projections of millets in Maharashtra (MT).

Year	Total demand	Total supply	Surplus/deficit
2011	3.07	3.50	0.43
2026	3.62	2.59	-1.03
2031	3.78	1.67	-2.11
2036	3.90	0.76	-3.14

Table 6: Millet-wise demand and supply gap projections in Maharashtra (MT).

Year	Sorghum	Pearl millet	Finger millet	Small millets
2011	1.11	0.20	-0.05	-0.06
2026	-0.02	0.03	-0.12	-0.08
2031	-0.90	-0.11	-0.15	-0.10
2036	-1.77	-0.23	-0.19	-0.11

Supply projections of millets

The supply projections of millets in Maharashtra state are shown in (Table 4), which are derived based on the Compound Annual Growth Rates (CAGR) observed over the last ten years. The production growth rates for sorghum, pearl millet, finger millet and small millet were found to be -5.59%, -2.79%, -5.29% and -6.59%, respectively. According to the CAGR approach, the projected supply of millet exhibits a declining trend over the years. By 2036, the supply is estimated to be 0.28 MT for sorghum, 0.46 MT for pearl millet, 0.02 MT for finger millet and zero for minor millet. Consequently, the overall supply of millets is projected to reach only 0.76 MT. These findings align with similar studies conducted by Sreekala *et al.* (2023) and Reddy *et al.* (2013), which also reported a downward trend in millet supply. However, it is worth mentioning that Shirish and Singh (2013) contradict these results by suggesting an increase in pearl millet supply in the future for the state of Rajasthan, attributed to a gradual expansion in the cultivation area.

Demand and supply gap

The estimated total demand and supply gaps for millets in Maharashtra state are shown in (Table 5). In 2011-12, the supply was sufficient to meet the total demand, resulting in a surplus of 0.43 MT. However, in future the deficit in supply becomes apparent, with a projected shortfall of 1.03 MT in 2026, 2.11 MT in 2031 and 3.14 MT in 2036. It is important to note that despite the deficit in millet supply, the country's overall production of food grains is expected to be in surplus by 2030 due to paddy and wheat crops, as highlighted by Barman and Toor (2017).

Table 6 shows the difference between the total supply and the average demand, which indicates the millet-wise future deficiency or surplus. Sorghum will have a net deficit of 1.77 MT by 2036; likewise, pearl millet, finger millet and small mill*et* also face a net deficiency of 0.23 MT, 0.19 MT and 0.11 MT, respectively.

Conclusion

The importance of sustainable production and consumption systems is on the rise, with millets emerging as a crop species that offers a sustainable solution for food and nutritional security. However, millet consumption per capita in India remains well below the Recommended Dietary Allowance (RDA). While income levels have only a moderate impact on millet demand, price fluctuations play

a significant role, with demand elasticity estimated between -0.877 and -1.024. Enhancing the status of millets in India will require several targeted interventions: the development of high-yielding varieties suited to diverse products, establishment of seed hubs to ensure a stable supply of high-quality seeds and addressing research and development gaps in areas such as shelf-life extension for processed millet products, primary and secondary processing equipment and comprehensive nutritional assessments. Additionally, scaling successful millet value chain models, providing incentives for millet cultivation and incorporating millets into public food distribution systems are essential steps for strengthening millet production and consumption in India.

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Disclaimers

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Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee

Conflict of interest

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