**Assessing the Role of Small Millets in Assam's Agrifood System: A Comparative Analysis with Major Crops**

**Abstract**

The agrifood system in Assam is confronted with intertwined challenges including climate change, malnutrition, resource constraints, and unsustainable cropping patterns. In this context, small millets are nutritious, drought-resistant, and low-input crops offering promising solutions, particularly for ecologically fragile regions like Assam. The study is primarily based on the secondary data collected from published sources like the Economic Survey of Assam, Statistical Hand Book Assam, and Agricultural Statistics at a Glance etc. The study performs a comparative analysis of small millets vis-à-vis major crop groups (rice, pulses, oilseeds, fruits and vegetables) using the Compound Annual Growth Rate (CAGR), Instability Analysis (Coefficient of Variation), Markov Chain Analysis and Terms of Trade (yield and output).A continuous decline in area under both small millets and rice was observed, with small millets showing greater instability and lowest area retention (19 percent) as per Markov analysis when compared to Kharif and Rabi rice that retained 86 percent and 78 percent of their respective areas, reflecting farmers' strong preference for rice. The Terms of Trade analysis showed that small millets suffer from unfavorable trade terms compared to rice, pulses, and fruits and vegetables, though they perform slightly better than oilseeds in yield-based comparisons.

Keywords: Small Millets, Growth Rate, Markov Chain, Terms of Trade, Assam

**Introduction**

The global agrifood system faces multiple complex challenges, including hunger, undernutrition, obesity, population growth, limited natural resources, and climate change. To address these issues, sustainable food production should empower mostly small and marginal farmers and agribusiness enterprises, build resilient value chains, and improve consumer access to affordable, diverse, and healthy diets. Millets, thus, can be a solution to offer an affordable and nutritious alternative that can be grown in harsh climates and arid regions with minimal external inputs (FAO, 2023). Millet, also known as "The Forgotten Grains," has been an essential part of human civilization for thousands of years. The millets as drought-resistant “Nutri-Cereals” are experiencing a renaissance in cultivation and consumption as a key crop in sustainable agrifood systems (Meena *et al*., 2021). At present, a few varieties of small millets are sporadically grown by the tribal farmers and consumed in parts of Assam and adjoining the North-Eastern states (Tripura and Sikkim) in limited quantity (Palanna *et al.,* 2020). In the traditional pockets of Karbi Anglong, millets are cultivated in Jhum along with rice, maize, tubers, spices and vegetables (Chakraborty and Choudhary, 2023). The state, however, continues to exhibit very low levels of millet consumption both in rural and urban areas, as reported by NSO surveys (2011 and 2022). Assamese cuisine has long been centered on rice as the staple grain and thus, millets have not historically been a significant part of the Assamese food culture, unlike in states like Karnataka or Rajasthan.

Small millets provide an opportunity for diversified cropping systems. The benefits of millet for health and nutrition, as well as its resilience to environmental stresses like drought, have led to a resurgence of interest in these nutri-cereals in recent years, although with an improvement in the yield of millets in the region, production remained static as the area under cultivation continued to decline, losing ground to rice and wheat.With the launch of the Assam Millet Mission in 2022 in synergy with Prime Minister’s aim of Atmanirbharta (self-sufficiency) across 15 districts of the state, several beneficiaries who had previously not practiced millets cultivation have taken up millets cultivation, particularly foxtail millet, finger millet and proso millet to raise nutrition quotient and with an objective to double their income. Promoting crop diversification through small millets in the state can support farmers in addressing challenges related to nutrition, environmental sustainability, and livelihood security in the years ahead. This paper evaluates the dynamics of small millets cultivation vis-a-vis major crops in Assam from the period of 2002-03 to 2021-22.

**Materials and Methods**

**Compound Annual Growth Rate**

The change in the area of the crop groups including paddy, small millets, pulses, oilseeds and fruits and vegetables was investigated using tabular analysis and the compound annual growth rates (CAGR) was estimated as follows

Yt = ABt e

Writing it in semilog form as,

ln Yt = ln A + (ln B) t + ln e

where, B = (1+r)

Yt = Area of land use categories/ crop groups in the tth period,

t = Time variable (1, 2, 3,……, n),

A and B = Parameters to be estimated,

r = Compound growth rate, and

e = Error-term.

The exponential function was transformed to the semilog model and estimated using ordinary least square (OLS) (Srivastava *et al*., 2010).

To examine the stability in area of the crop groups including paddy, small millets, pulses, oilseeds and fruits and vegetables, coefficient of variation (CV) was estimated which together with CAGR.

where, σx = Standard deviation of X, and

X̄ = Mean of x

**Markov Chain Analysis**

The dynamics of change in crop groups was examined by using stationary form of the first order Markov Chain model. The general form of the first order Markov model is:

where,

Qjt = Area under the ‘jth’ crop during the year t,

Qj,t - 1 = Area under the ‘jth’ crop during the year t-1,

Pij = Probability that area shifts from the ith crop to the jth crop, and

r = Number of crops included in the model.

The transitional probabilities Pij have the properties

0≤ Pij ≤1;

The P matrix was estimated in the linear programming framework using method of minimization of mean absolute deviation as,

Min 0 P\* + Ie

Subject to

XP\* + e = Y

GP\* = 1

P\* ≥ 0

where,

P\* is a vector probabilities Pij,

0 is a vector of zeros,

I is an identity matrix of appropriate dimension,

e is the vector of absolute errors,

Y is the vector of area of each crop,

X is a block diagonal matrix of lagged values of Y, and

G is a grouping matrix to add the row elements of P arranged in P\* to unity.

**Terms of Trade**

The Terms of Trade (TOT) in terms of Yield and Output was calculated between competing crops which indicates how one crop is preferred to other competing crops over the years which was used by Srivastava *et al*.,2010.

Thus, TOT (Yield) = Yield (crop A)/ Yield (crop B)

and, TOT (Output) = [{value of output/area} (crop A)/ {value of output/area} (crop B)]

**Results and Discussion**

In Assam, small Millets were cultivated in area of 3653 ha, and produced 2145 tonnes with a productivity of 587 kg/ha (GoI, 2021-22). In contrast, findings from a primary survey conducted during 2023 and 2024 revealed that foxtail millets and finger millets were grown over an estimated 1,100 hectares, resulting in a total production of around 131 tonne s, but with a notably lower productivity of 119 kg/ha.

**Growth Rate and Instability Analysis**

Table 1 summarizes the Compound Annual Growth Rate (CAGR) and Instability (measured by coefficients of variation, CV) in the area of rice, small millets, pulses, oilseeds and fruits and vegetables in Assam during the period 2002-03 to 2021-22. Among the selected crops, the total area under rice had declined over the years except during QE 2011-12 which showed a positive CAGR of 2 percent. Both Kharif and Rabi rice areas have shown an overall declining trend with moderate instability ranging from 1 to 5 percent. Similar trend can be seen in the case of small millets except for QE 2016-17, but with higher rates as compared to rice. The overall decline of area under small millets from the period 2002-03 to 2021-22 is -2 percent.

The higher instability of small millets ranging up to 20 percent is an indicative of uneven land distribution for small millets, because of changing cropping pattern in the state, mostly towards fruits and vegetables, and Rabi pulses that have emerged as promising crops showing a positive growth trends over the entire period from 2002-03 to 2021-22, although with high variability ranging up to 20 percent.

Das *et al.* (2019) also found a declining trend in pearl millet and finger millet area in India from the period 1959-60 to 2017-18. In India, Anbukkani *et al.* (2017) stated that the trade-off with rice and wheat was the primary reason for the fall in area and production of small millets. There is a poor policy support for coarse cereals including millets but favourable policies for the production of oilseeds such as sunflower and soybeans, as well as cash crops such as cotton that became increasingly profitable as yields and prices increased in response to rising consumer demand. Nayak *et al.* (2024) also observed changes in the cropping pattern over time and low millets consumption among the rural and urban masses as major reasons for the declining area and production of millets in India.

**Dynamics of Area Substitution**

To examine the dynamics of area substitution between the crop groups, Markov Chain Analysis was done to estimate transition probability matrix (expressed in percentage terms) that explains how the area among the competing crops has shifted over time. The rows of the matrix represent the area that the corresponding group lost to the other group. Columns, on the other hand, show how much area the respective group obtained.

The results given in Table 2 show that during 2002-03 to 2021-22, highest area of 86 percent was retained under Kharif rice followed by 78 percent under Rabi rice among all the other crops, showing minimal diversification. Furthermore, both Kharif and Rabi rice and small millets area was not found to have shifted to pulses or oilseeds significantly and the transition probability matrix has indicated a clear preference for rice over pulses and oilseeds. Similar results were found by Srivastava *et al.* (2010), and Manasa *et al.* (2024) while examining the dynamics of area substitution between cereals, pulses, oilseeds and other crops.

The small millets could retain only 19 per cent of their area. There was no substitution among small millets and other crops, except Rabi rice and Kharif oilseeds. This suggests that small millets are grown mostly in a manner that is comparatively constant with farmers showing little interest to grow these crops. The shift also indicated low market demand, limited profitability, or poor price realization for small millets in comparison to oilseeds and pulses. Furthermore, compared to small millets counterparts, rice would have produced larger per-hectare economic returns because of their higher yields, price support, and market support (Bisen *et al.*, 2023).

**Terms of Trade (TOT)**

The terms of trade (TOT) between the crops have been examined in terms of yield and output in Table 3. Small millets have lower yield and output when compared with rice, pulses, and fruits and vegetables. Therefore, TOT was found to be against small millets. Notably, terms of trade in terms of yield (TOTy) between small millets and oilseeds was only found to be in favour of small millets because of relatively lower yield of oilseeds.

Small millets have the potential to become new staple crops, particularly in areas where hunger is a problem (Muthamilarasan and Prasad, 2021). They tend to withstand prolonged exposure to drought and their water needs are less than other cereals such as wheat and rice (Padakandla, 2016). Small millets, once traditional staples, are regaining popularity for their drought resistance and nutritional value. Though lower-yielding, they fetch higher prices in niche markets. Rising demand or policy support could improve their RTOT as compared to fine cereals such as rice and wheat.

**Conclusion**

This shift in cropping pattern led to a consistent decline in area of rice and small millets in Assam from 2002-03 to 2021-22, with small millets exhibiting greater instability while analysing the growth rate and instability, further influenced by changing market demands and better returns from crops like fruits, vegetables, and Rabi pulses, which have shown positive growth despite high variability. The Markov Chain Analysis highlighted limited crop diversification in Assam, particularly with rice retaining a dominant share of cultivated area from 2002-03 to 2021-22. Kharif and Pre-kharif rice retained 86 percent and 78 percent of their respective areas, showing a strong preference among farmers for rice cultivation. In contrast, small millets retained only 19 percent of their area, with minimal shifts to or from other crop groups, reflecting low adaptability and limited farmer interest. Pulses and Rabi oilseeds have shown minimal transition potential to small millets, suggesting targeted interventions are necessary if these areas are to be converted. The area lost under small millets has often been offset by rising productivity and shifts toward more lucrative commercial crops including fruits and vegetables. The terms of trade analysis revealed that small millets consistently have lower yields and outputs compared to rice, pulses, and fruits and vegetables, making the RTOT generally unfavourable for small millets. However, the only exception is in comparison with oilseeds, where small millets show a relative advantage in yield-based RTOT (RTOTy), due to the comparatively lower yields of oilseeds. Provision of incentives for farmers transitioning from rice to less resource-intensive crops like millets, pulses, and oilseeds. Bridging the normative gap through increased millet production and strategic integration into public nutrition programs can contribute to food security, climate resilience, and nutritional sufficiency in Assam. Prioritizing millets in agricultural planning is crucial to meet future dietary needs and achieve sustainable food systems.

**Conflict of interest**

All authors declare that they have no conflict of interest.

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**Table 1: Compound Growth Rate (CAGR) in the area of the crops: 2002-2022 (percent)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Crops** | | **QE 2006-07** | **QE 2011-12** | **QE 2016-17** | **QE 2021-22** | **2002-03 to 2021-22** |
| Rice | *Kharif* | -3.72  (5.88) | 1.69  (2.84) | -0.21  (0.78) | -0.72  (2.47) | -0.38  (4.31) |
| *Rabi* | -4.98  (7.23) | -5.88  (9.02) | 0.92  (1.99) | -2.09  (3.15) | -0.23  (10.90) |
| *Total* | -3.36  (5.24) | 2.12  (4.33) | -0.03  (1.06) | -0.94  (4.37) | -0.12  (3.83) |
| Small Millets  *Kharif* | | -3.00  (5.54) | -4.65  (12.59) | 3.38  (15.69) | -2.09  (3.43) | -2.65  (19.57) |
| Pulses | *Kharif*  *(Tur)* | -0.74  (3.01) | 1.73  (9.50) | -0.31  (3.46) | 1.56  (3.02) | -0.93  (8.43) |
| *Rabi*  *(Gram, Urad, Moong, Lentil)* | -2.35  (4.65) | 2.26  (4.08) | 0.19  (2.48) | -2.04  (3.39) | 2.31  (14.58) |
| *Total* | -2.24  (4.51) | 2.24  (4.23) | 0.18  (2.36) | -1.90  (3.16) | 2.14  (13.66) |
| Oilseeds | *Kharif*  *(Catorseeds, Sesamum, Nigerseed)* | -2.13  (5.06) | -2.18  (4.89) | -1.34  (3.30) | -1.01  (1.63) | -1.83  (11.49) |
| *Rabi*  *(Rapeseed-Mustard, Linseed)* | -4.01  (7.61) | 0.89  (2.55) | 1.08  (1.76) | -0.08  (0.59) | 1.12  (8.81) |
| *Total* | -3.85  (7.31) | 0.63  (2.49) | 0.93  (1.52) | -0.14  (0.60) | 0.91  (7.70) |
| Fruits & Vegetables | | 14.07  (19.55) | -1.39  (3.09) | 1.50  (3.05) | 0.94  (1.80) | 1.47  (11.36) |

Figure in parentheses indicates the coefficients of variation (CV)

**Table 2: Transitional probability matrix for dynamic changes of crops in Assam from 2002-03 to 2021-22**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Gain | Shift | | | | | | | | |
| Crops | Kharif Rice | Rabi Rice | Small Millets | Kharif Pulses | Rabi Pulses | Kharif Oilseeds | Rabi Oilseeds | Fruits and Vegetables |
| Kharif Rice | 0.8622 | 0.0208 | 0.0000 | 0.0019 | 0.0000 | 0.0036 | 0.0362 | 0.0753 |
| Rabi Rice | 0.0000 | 0.7829 | 0.0059 | 0.0040 | 0.0000 | 0.0065 | 0.0000 | 0.2007 |
| Small Millets | 0.0000 | 0.0000 | 0.1968 | 0.0962 | 0.0000 | 0.7071 | 0.0000 | 0.0000 |
| Kharif Pulses | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| Rabi Pulses | 0.0000 | 0.1559 | 0.0000 | 0.0000 | 0.5878 | 0.0000 | 0.2564 | 0.0000 |
| Kharif Oilseeds | 0.8867 | 0.0000 | 0.1122 | 0.0011 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Rabi Oilseeds | 0.0000 | 0.0631 | 0.0000 | 0.0000 | 0.1250 | 0.0000 | 0.6193 | 0.1927 |
| Fruits and Vegetables | 0.5964 | 0.0000 | 0.0000 | 0.0000 | 0.0473 | 0.0000 | 0.0012 | 0.3551 |

Data source: Authors’ Estimate

**Table 3: Terms of Trade (TOT) of the crop group**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Period** | **QE 2006-07** | | **QE 2011-12** | | **QE 2016-17** | | **QE 2021-22** | |
|  | TOTy | TOTo | TOTy | TOTo | TOTy | TOTo | TOTy | RTOTo |
| R-SM | 2.82 | 3.24 | 3.28 | 3.16 | 3.42 | 6.59 | 3.41 | 7.50 |
| P-SM | 1.07 | 3.77 | 1.09 | 6.84 | 1.18 | 7.10 | 1.22 | 6.67 |
| O-SM | 0.42 | 3.21 | 0.48 | 5.14 | 0.55 | 5.57 | 0.58 | 4.92 |
| FV-SM | 23.07 | 25.00 | 22.95 | 45.45 | 21.69 | 48.15 | 20.68 | 54.02 |

Data source: Authors’ estimate

TOTy = Terms of Trade (yield), TOTo = Terms of Trade (output)

R = Rice, SM = Small Millets, P = Pulses, O = Oilseeds, FV = Fruits and Vegetables