

RESEARCH ARTICLE

Mapping Season-Specific Efficient Cropping Zones for Maize and Sorghum in Tamil Nadu

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ABSTRACT

Maize and sorghum are important crops in Tamil Nadu, contributing substantially to food, feed and industrial uses and to livelihood security. Their cultivation occurs under distinct seasonal environments. The area of production and productivity of both crops vary widely across districts and seasons due to climatic conditions, irrigation access and management practices. Identifying season-specific efficient cropping zones is therefore essential for improving productivity, optimizing resource use and ensuring sustainable crop production under changing climatic conditions. The present study delineated season-wise efficient cropping zones for maize and sorghum in Tamil Nadu using district-level time-series data on area of production and productivity for the period 2013-14 to 2023-24. Season-wise (Kharif and Rabi) analysis was performed using RSI and RYI to classify the district into different efficient zones. The results revealed that four districts were identified as the most efficient cropping zones for maize during the kharif season, while eleven districts emerged as the most efficient zones during the rabi season, predominantly located in the western and central regions of Tamil Nadu. In contrast, a large proportion of districts in both seasons were classified as not efficient cropping zones for maize, indicating limited suitability and management constraints. Sorghum efficient cropping zones were largely concentrated in semi-arid and dryland districts, where six districts were identified as the most efficient cropping zones during both kharif and rabi seasons, highlighting the crop's role as a low-input and climate-resilient crop. Overall, the findings provide a scientific basis for season-specific crop planning and support targeted intensification in efficient zones to enhance productivity, profitability and sustainability.

Received: 28 Nov 2025

Revised: 19 Feb 2026

Accepted: 21 Mar 2026

Keywords: *Efficient cropping zones, Relative spread index, Relative yield index, Maize, Sorghum*

INTRODUCTION

Agriculture and allied sectors play a vital role in the rural economy of Tamil Nadu by providing livelihoods, ensuring food and nutritional security and contributing

to overall socio-economic development. Although agriculture contributes about 6% to the gross state value added (GSVA) of Tamil Nadu, it remains the primary

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source of employment in rural areas, supporting 41.1% of the rural workforce. Crop diversification is supported by extensive land availability and heterogeneous agro-climatic environments.

Among the food crops, maize (*Zea mays* L.) is the third most important grain crop in India after rice and wheat. Maize is a highly adaptable and versatile crop that plays a significant role in global agricultural and food systems. Owing to its high genetic yield potential, it is often referred to as the queen of cereals and exhibits wide adaptability across diverse agro-climatic conditions (Infant Paul *et al.*, 2023). In India, maize is cultivated on 120.91 lakh hectares, with a total production of 434.09 lakh tonnes and an average productivity of 3,590 kg ha⁻¹. In Tamil Nadu, maize occupies about 4.85 lakh hectares with a production of 26.63 lakh tonnes and productivity of 5,487 kg ha⁻¹ (Indiastat). The leading maize-producing states in India include Telangana, Andhra Pradesh, Maharashtra, Karnataka, Bihar, Rajasthan, Uttar Pradesh, and Madhya Pradesh. In Tamil Nadu, maize is cultivated during both the Kharif and Rabi seasons under irrigated and rainfed conditions. The relatively higher productivity observed in Tamil Nadu reflects the state's favourable agro-climatic conditions for maize cultivation. (Felix *et al.*, 2018). Maize occupies a strategic position in India's agri-food system owing to its wide spectrum of food, feed and industrial applications. The crop is consumed in diverse forms such as popcorn, green cobs, sweet corn, baby corn, grain maize, and contributes nearly 9% to the national food basket (Manoj *et al.*, 2022). In Tamil Nadu, maize has assumed increasing importance, largely driven by the growing demand from the livestock feed and industrial sectors. India's prominent global standing in egg and broiler chicken production has substantially increased the dependence on maize as a principal component of poultry feed. Furthermore, maize is increasingly processed for bioethanol production for blending with vehicle fuels, highlighting its expanding role in the renewable energy sector. Collectively, these end uses underscore the significance of maize as a versatile crop with strong, sustained demand. (Kiruthika *et al.*, 2023). The demand for and production of maize are increasing more rapidly than those of other major commodities. It is estimated that the demand for maize will continue to increase in the coming days (Yadav *et al.*, 2016).

Sorghum [*Sorghum bicolor* (L.) Moench] is a staple food crop for millions of people in semi-arid regions,

ranking fifth globally after rice, wheat, maize, barley, and fourth in importance in India. The crop plays a vital role in ensuring food security in dryland and semi-arid areas. It is often referred to as a "Miracle Nutri-cereal" because of its significant contribution to nutritional and health security (Upadhyaya *et al.*, 2024). In recent years, sorghum has gained renewed importance as a "healthy food" due to its rich nutrient profile and is widely known as the "King of Millets" (Hossain *et al.*, 2023). Sorghum is a multipurpose crop used for grain, animal feed, fodder, pasture, fibre, bioethanol, alcoholic beverages and as a raw material for building purposes (Kazungu *et al.*, 2023).

About 19.5% of the world's population and nearly 27% of India's population depend on sorghum as a primary food source. Globally, sorghum is cultivated on about 41 million hectares, producing 64.20 million tonnes with an average productivity of 1.60 tonnes ha⁻¹ (Ammayappan *et al.*, 2025). In India, the crop is grown over 39.95 lakh hectares with a production of 49.55 lakh tonnes and a productivity of 1,240 kg ha⁻¹. In Tamil Nadu, sorghum occupies about 3.39 lakh hectares, with a production of 4.10 lakh tonnes and a productivity of 1,211 kg ha⁻¹ (Indiastat). Maharashtra leads sorghum production in India (18.45 lakh tonnes), followed by Karnataka (8.15 lakh tonnes), Rajasthan (5.20 lakh tonnes) and Tamil Nadu. Compared with the global average, sorghum productivity in India remains relatively low, mainly due to its predominance under rainfed conditions and exposure to unfavourable climatic stresses during critical growth stages (Ammayappan *et al.*, 2023).

Crop choice at the farm level is largely influenced by market demand and yield performance. However, crop suitability is dynamic and varies across years and seasons, highlighting the need for regular scientific reassessment of regional adaptability. Such periodic evaluations help farmers adopt suitable or alternative cropping systems that enhance productivity and farm profitability (Poornima *et al.*, 2008). Potential crop growing regions can be identified using indices such as the Relative Yield Index (RYI) and the Relative Spread Index (RSI), which together facilitate the delineation of efficient cropping zones. Further, the mapping of season-wise efficient cropping zones provides a robust framework for optimizing crop planning and resource allocation under diverse agro-climatic conditions (Ammayappan *et al.*, 2026).

In addition, the delineation of season-wise ECZs can support the formulation of evidence-based policies aimed at promoting location-specific crop cultivation, strengthening extension advisory services and guiding input distribution and investment planning (Thavaprakash et al., 2008). Considering these aspects, the present study was undertaken to identify season-wise efficient cropping zones for maize and sorghum in Tamil Nadu.

MATERIALS AND METHODS

Study area: The season-wise efficient cropping zone for maize and sorghum study encompasses the entire Tamil Nadu region, spanning from 7.875°S to 13.083°N in latitude and 76.5°E to 80.375°E in longitude (Figure 1)

Data collection: The season-wise efficient cropping zones for maize and sorghum were analysed across all districts of Tamil Nadu. Hence, time series data on the area of production and productivity of maize and sorghum for both kharif and rabi seasons were collected for each district and for the state as a whole. These data pertain to the period 2013-14 to 2023-24 (11 years) and were sourced from the respective season and crop reports published by the Department of Economics and Statistics, Government of Tamil Nadu.

Methodology Adopted: The methodology proposed by Kanwar (1972), involving the computation of the Relative Spread Index (RSI) and Relative Yield Index (RYI), was adopted to delineate season-wise

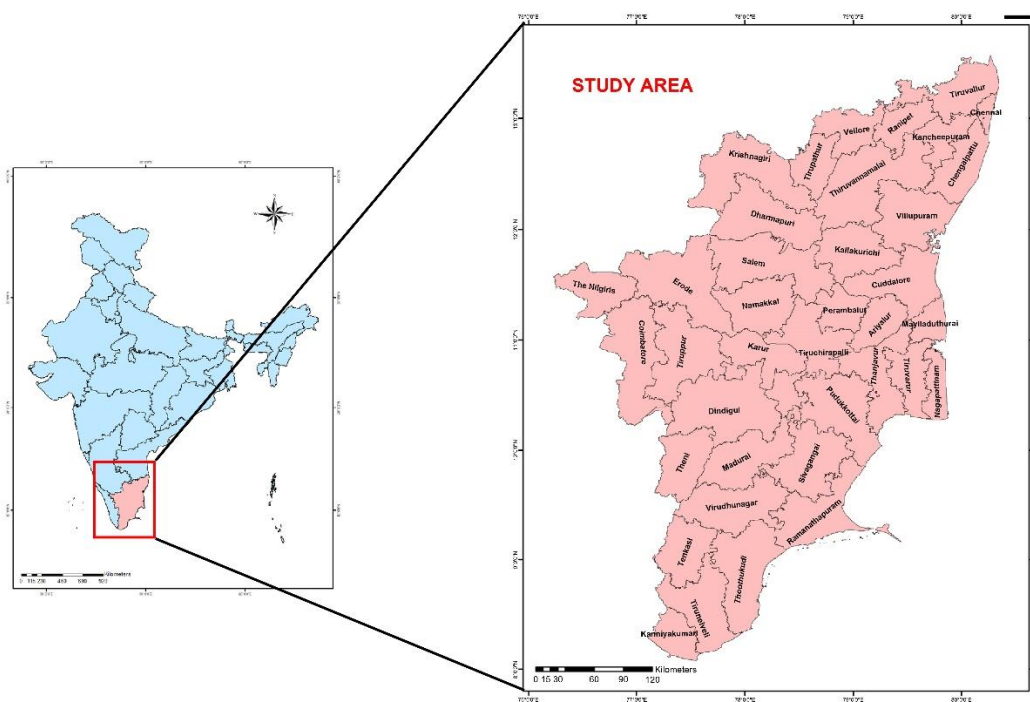


Fig.1. Study Area Map

Table 1: The criteria for the Effective Cropping Zone

Category No.	RSI	RYI	Combination of RSI and RYI	Cropping Zone
1.	>100 (High)	>100 (High)	High + High	Most Efficient Cropping Zone (MECZ)
2.	>100 (High)	< 100 (Low)	High + Low	Area Efficient Cropping Zone (AECZ)
3.	<100 (Low)	>100 (High)	Low + High	Yield Efficient Cropping Zone (YECZ)
4.	<100 (Low)	< 100 (Low)	Low + Low	Not Efficient Cropping Zone (NECZ)

RSI - Relative Spread Index; RYI – Relative Yield Index



efficient cropping zones for maize and sorghum in Tamil Nadu. The criteria for identifying the efficient cropping zones are furnished in Table 1. Multi-year average RSI and RYI values were used to minimize interannual variability. Districts exhibiting consistent performance across seasons and years were considered reliable, ensuring that the identified efficient cropping zones reflect stable spatial patterns.

Computation of RSI and RYI: The analysis was carried out separately for the kharif and rabi seasons for maize and sorghum to capture seasonal variability in area, production and productivity. This season-wise stratification ensures that differences in monsoon dependence, climate variability, irrigation availability, and crop durations are adequately addressed. The computed values of RSI and RYI for different seasons across Tamil Nadu were furnished in Table 2. Districts were classified into different efficient cropping zones according to the criteria presented in Table 3.

$$RSI = \frac{\text{Area of a particular crop expressed as \% of the total cultivable area in the district}}{\text{Area of crop expressed as \% to the total cultivable area in the state}} \times 100$$

Where RSI: Relative Spread Index

$$RYI = \frac{\text{Mean yield of a particular crop in a district (Kg/ha)}}{\text{Mean yield of crop in the state (Kg/ha)}} \times 100$$

Where RYI: Relative Yield Index

Mapping of season-specific: Efficient cropping zones was carried out using suitability indices (RSI and RYI). Based on RSI and RYI values, districts were classified into efficiency categories and spatially represented using GIS for maize and sorghum during the kharif and rabi seasons in Tamil Nadu (Figures 2, 3, 4, and 5).

RESULTS AND DISCUSSION

Decadal Trends for Maize in Tamil Nadu

Maize exhibited a strong and consistent expansion in area, production and productivity across decades in Tamil Nadu (Table 4). The area under maize increased sharply from 12.7 thousand ha in 1965-75 to 368.2 thousand ha during 2015-23, accompanied by a substantial rise in production from 12.9 to 2488.5 thousand tonnes. Productivity showed remarkable improvement from 1029 kg ha⁻¹ in 1965-75 to 6715 kg ha⁻¹ in 2015-23, with particularly large gains after 2005-06, corresponding to the widespread adoption

of high-yielding hybrids, better input management, and the expansion of maize area under irrigated conditions. These trends clearly demonstrate the increasing dominance of maize over sorghum in the state's agricultural economy.

Efficient Cropping Zones - Maize

The season-wise classification of efficient cropping zones for maize across Tamil Nadu for both kharif and rabi seasons is summarized in Table 3.

Kharif Maize: In Tamil Nadu, kharif maize is sown during June-July under both rainfed and irrigated production systems. During the kharif season, the most efficient cropping zones for maize, characterized by high RSI and RYI, were identified in Erode, Kallakurichi, Perambalur and Salem districts of Tamil Nadu. The superior performance in these districts can be attributed to better crop establishment, supported by relatively assured irrigation facilities throughout the crop growth stages and to the wider adoption of maize cultivation among farming communities (Abinaya et al., 2022). The districts such as Dindigul, Namakkal, Pudukottai, Tenkasi, Theni, Thiruppur, and Tirunelveli fall under the yield-efficient cropping zones. The higher maize productivity in these regions may be attributed to the adoption of high-yielding, pest and disease resistant maize varieties and the implementation of adaptive crop management practices by farmers. However, improved extension approaches may be employed to promote the expansion of cultivated area, and the factors contributing to the poor spatial spread of maize cultivation require further investigation (Gebere et al., 2021). The districts of Ariyalur, Cuddalore, Madurai, Tiruchirapalli, and Villupuram is classified as an efficient cropping zone, as they exhibit high RSI and low RYI. These districts exhibit the wider special spread and low productivity levels mentioned, which substantially yield gaps. The yield limitations in maize may be attributed to sub-optimal agronomic practices, non-availability of quality inputs, incidence of epidemic pest outbreaks, climate variability and soil-related constraints. (Sidahmed et al., 2025). Districts including Chengalpattu, Chennai, Coimbatore, Dharmapuri, Kancheepuram, Kanyakumari, Karur, Krishnagiri, Mayiladuthurai, Nagapattinam, Ramanathapuram, Ranipet, Sivagangai, Thanjavur, The Nilgiris, Tirupathur, Tiruvallur, Tiruvannamalai, Tiruvarur, Thoothukudi, Vellore and Virudhunagar are classified as not efficient

Table 2. Computed season-wise values of RSI and RYI for maize and sorghum in efficient cropping zones of Tamil Nadu

SI No.	District Name	Kharif Maize		Rabi Maize		Kharif Sorghum		Rabi Sorghum	
		RSI	RYI	RSI	RYI	RSI	RYI	RSI	RYI
1	Ariyalur	390.5	80	127.5	100	11.2	104.4	7.1	100
2	Chengalpattu	0.2	39.8	0.2	51.5	8.6	70	0	16.4
3	Chennai	0	0	0	0	0	0	0	0
4	Coimbatore	27.2	99.1	41.7	103.2	276.1	78.2	220.3	60.6
5	Cuddalore	184.1	65.7	56.7	100	1.4	92.2	0.1	70.9
6	Dharmapuri	80.4	87.1	26.4	98.7	253.8	134.7	64.5	94
7	Dindigul	92.5	101.9	276.2	119.2	217.9	126.2	459.8	108.8
8	Erode	211	100.4	107.4	124.8	2.2	59.3	2.1	42.7
9	Kallakurichi	224.8	112.3	125.4	118	0.1	73.5	0.1	35.4
10	Kancheepuram	0.2	42.5	0.1	63.5	0.2	60.4	0.2	62.9
11	Kanyakumari	0.2	64.4	0.4	54	0	42.4	0	0
12	Karur	22.9	99.1	31.2	100	415.4	65.8	426.3	52.3
13	Krishnagiri	24.7	98.5	11.5	100	49.5	147.5	15	100
14	Madurai	170.6	68.8	203.9	95.1	181.2	163.5	103.5	164.9
15	Mayiladuthurai	0.4	78.2	0.3	74.7	0.1	65.9	4.2	67.8
16	Nagapattinam	0.1	29.6	0.1	64.5	0	8.8	0.1	40.3
17	Namakkal	55.5	106.2	66.3	120	628.5	59.8	546.2	79.4
18	Perambalur	1313.7	108.2	437	100	27.3	108.4	13.1	81.4
19	Pudukottai	46.1	100.3	38.1	100	4.5	98.8	3.2	100
20	Ramanathapuram	0.9	18.1	9.5	100	13	23.2	67.4	110.8
21	Ranipet	0.1	78.2	0	84.4	13.9	90.8	10.5	73.2
22	Salem	272.1	122.6	154.8	136.3	291.9	93.4	214	90.9
23	Sivagangai	1.3	99.1	1.1	100	5.6	98.8	6.4	100
24	Tenkasi	66.9	101.8	336.3	75.8	71.2	90.8	10.7	73.2
25	Thanjavur	5.7	99.1	4.8	97.3	1.2	67.6	1	57.6
26	The Nilgiris	0.1	46.3	0	26	0	26.2	0	0
27	Theni	77	104.8	122.2	109.5	116.2	218.3	153.1	280.6
28	Thirupathur	58.5	46.3	33.7	84.4	178	116.9	29.8	73.2
29	Thiruppur	85.3	117.5	257.5	133.8	204.1	31.1	409.6	17.1
30	Thiruvallur	0.3	61.4	0.9	92	2.5	83.2	0.5	73.1
31	Thiruvannamalai	7.3	99.1	10.2	95.6	3.3	98.8	3	100
32	Thiruvarur	0	46.3	0.1	55.3	0	8.4	0	16.6
33	Thoothukudi	55.4	60.6	471.3	58.2	33.5	34.7	166.4	134.8
34	Tiruchirapalli	218.5	90.8	80.8	100	385	99.8	207.7	148.3
35	Tirunelveli	26.1	102.5	166.3	102.8	24.2	197.6	14.4	100
36	Vellore	28.8	99.1	38.5	104.7	102.3	141.6	33.4	82.8
37	Villupuram	65.4	106.8	65.9	104.7	5.2	98.8	3	100
38	Virudhunagar	94.5	82.5	529.8	100.6	96.9	158.8	236.6	203.8



Table 3. Seasonal efficient cropping zones for maize and sorghum in Tamil Nadu

Sl. No	District Name	Kharif Maize			Rabi Maize			Kharif Sorghum			Rabi Sorghum		
		RSI	RYI	Results	RSI	RYI	Results	RSI	RYI	Results	RSI	RYI	Results
1.	Ariyalur	H	L	AECZ	H	H	MECZ	L	H	YECZ	L	H	YECZ
2.	Chengalpattu	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
3.	Chennai	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
4.	Coimbatore	L	L	NECZ	L	H	YECZ	H	L	AECZ	H	L	AECZ
5.	Cuddalore	H	L	AECZ	L	H	YECZ	L	L	NECZ	L	L	NECZ
6.	Dharmapuri	L	L	NECZ	L	L	NECZ	H	H	MECZ	L	L	NECZ
7.	Dindigul	L	H	YECZ	H	H	MECZ	H	H	MECZ	H	H	MECZ
8.	Erode	H	H	MECZ	H	H	MECZ	L	L	NECZ	L	L	NECZ
9.	Kallakurichi	H	H	MECZ	H	H	MECZ	L	L	NECZ	L	L	NECZ
10.	Kancheepuram	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
11.	Kanyakumari	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
12.	Karur	L	L	NECZ	L	H	YECZ	H	L	AECZ	H	L	AECZ
13.	Krishnagiri	L	L	NECZ	H	H	MECZ	L	H	YECZ	L	H	YECZ
14.	Madurai	H	L	AECZ	H	L	AECZ	H	H	MECZ	H	H	MECZ
15.	Mayiladuthurai	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
16.	Nagapattinam	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
17.	Namakkal	L	H	YECZ	L	H	YECZ	H	L	AECZ	H	L	AECZ
18.	Perambalur	H	H	MECZ	H	H	MECZ	L	H	YECZ	L	L	NECZ
19.	Pudukottai	L	H	YECZ	L	H	YECZ	L	L	NECZ	L	H	YECZ
20.	Ramanathapuram	L	L	NECZ	L	H	YECZ	L	L	NECZ	L	H	YECZ
21.	Ranipet	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
22.	Salem	H	H	MECZ	H	H	MECZ	H	L	AECZ	H	L	AECZ
23.	Sivagangai	L	L	NECZ	L	H	YECZ	L	L	NECZ	L	H	YECZ
24.	Tenkasi	L	H	YECZ	H	L	AECZ	L	L	NECZ	L	L	NECZ
25.	Thanjavur	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
26.	The Nilgiris	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
27.	Theni	L	H	YECZ	H	H	MECZ	H	H	MECZ	H	H	MECZ
28.	Thirupathur	L	L	NECZ	L	L	NECZ	H	H	MECZ	L	L	NECZ
29.	Thiruppur	L	H	YECZ	H	H	MECZ	H	L	AECZ	H	L	AECZ
30.	Thiruvallur	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
31.	Thiruvannamalai	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	H	YECZ
32.	Thiruvarur	L	L	NECZ	L	L	NECZ	L	L	NECZ	L	L	NECZ
33.	Thoothukudi	L	L	NECZ	H	L	AECZ	L	L	NECZ	H	H	MECZ
34.	Tiruchirapalli	H	L	AECZ	L	H	YECZ	H	L	AECZ	H	H	MECZ
35.	Tirunelveli	L	H	YECZ	H	H	MECZ	L	H	YECZ	L	H	YECZ
36.	Vellore	L	L	NECZ	L	H	YECZ	H	H	MECZ	L	L	NECZ
37.	Villupuram	L	H	AECZ	L	H	YECZ	L	L	NECZ	L	H	YECZ
38.	Virudhunagar	L	L	NECZ	H	H	MECZ	L	H	YECZ	H	H	MECZ

H – High; L – Low; MECZ – Most Efficient Cropping Zone; YECZ – Yield Efficient Cropping Zone; AECZ - Area Efficient Cropping Zone; NECZ – Not Efficient Cropping Zone

Table 4. Decadal trend in maize area, production, and productivity in Tamil Nadu

Block years	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)	Shift in productivity
1965-66 to 1974-75	12.7	12.9	1029	-
1975-76 to 1984-85	20.0	26.9	1394	365 (35.5%)
1985-86 to 1994-95	31.9	50.1	1576	183 (13.1%)
1995-96 to 2004-05	92.3	147.2	1611	35 (2.2%)
2005-06 to 2013-14	265.9	1276.9	4558	2947 (182.9%)
2015-16 to 2022-23	368.2	2488.5	6715	2157 (47.3%)

Source: Season and Crop Report, 2023-24

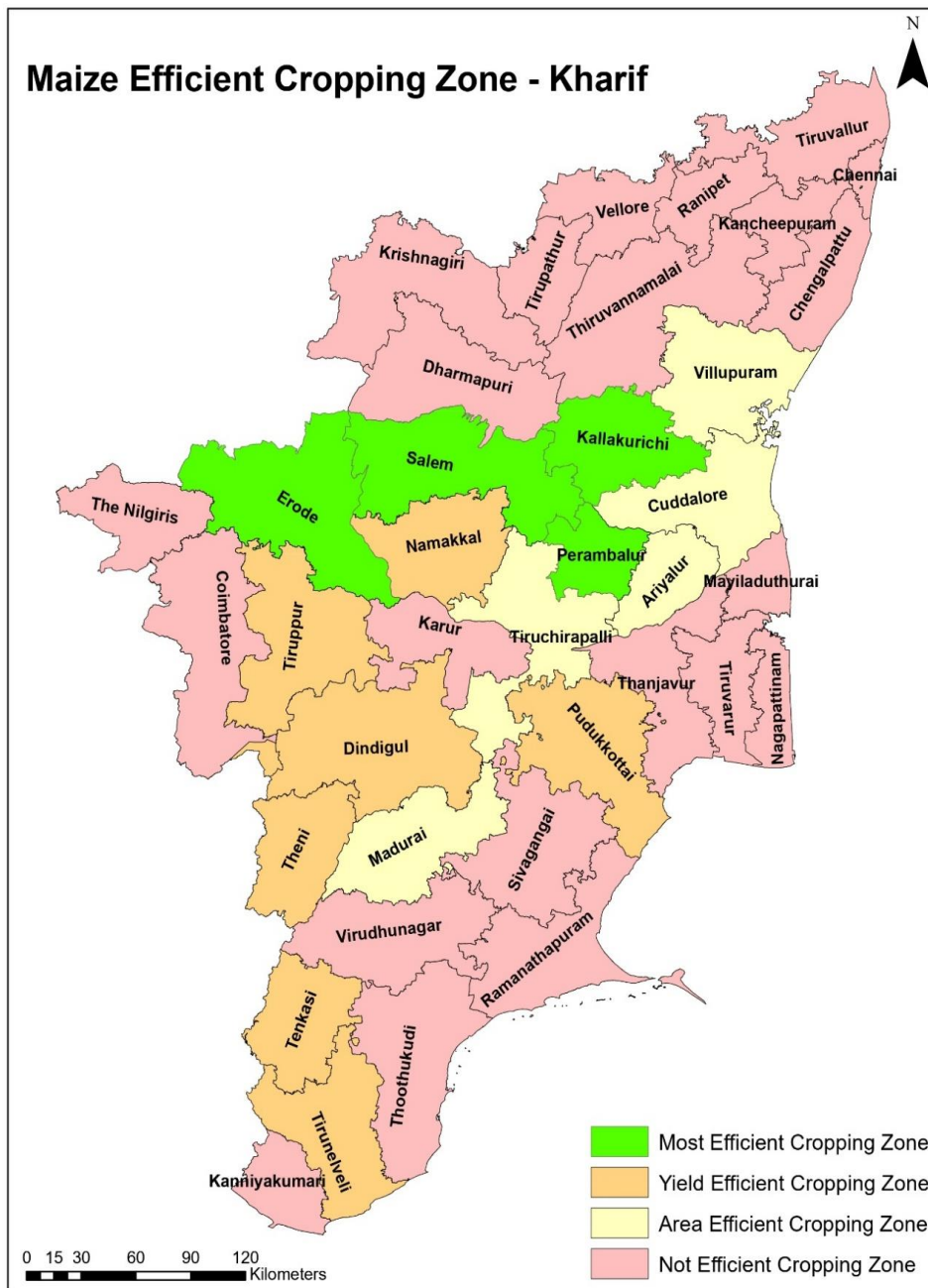


Fig. 2. Kharif Maize Efficient Cropping Zones in Tamil Nadu

cropping zones for maize during the Kharif season. Many districts classified as not efficient for Kharif maize are characterised by a combination of unfavourable agro-climatic conditions and management-related limitations, including rainfall variability, delayed monsoon onset, inadequate irrigation infrastructure, soil fertility depletion and non-site-specific nutrient management. These constraints are further compounded by episodic biotic stresses, persistent technology adoption gaps and socioeconomic factors that encourage maize cultivation in less suitable environments, ultimately resulting in low relative yields and their classification as non-efficient zones (Geethalakshmi *et al.*, 2024).

Rabi Maize: In Tamil Nadu, rabi maize is generally sown in September to October and is predominantly supported by supplemental irrigation rather than relying solely on rainfall. During the rabi season, the most efficient cropping zones for maize, characterised by high RSI and RYI, were identified in the Ariyalur, Dindigul, Erode, Kallakurichi, Krishnagiri, Perambalur, Salem, Theni, Tiruppur, Tirunelveli and Virudhunagar districts. Maize is sensitive to both excess moisture and moisture stress; therefore, an optimum and well-distributed water supply is essential throughout the crop growth period. In Tamil Nadu, rabi maize is generally sown during September to October and its growth coincides with the Northeast monsoon, which contributes a major share of the state's annual rainfall during October to December. Consequently, the growth and performance of rabi maize are closely linked to northeast monsoon rainfall patterns, influencing soil moisture availability and overall crop productivity (McDermid *et al.*, 2016). Yield efficient cropping zones for maize, characterised by high RYI and low RSI, include Coimbatore, Cuddalore, Karur, Namakkal, Pudukkottai, Ramanathapuram, Sivagangai, Tiruchirappalli, Vellore and Villupuram. In these districts, favourable climatic conditions and sound agronomic practices have supported higher maize yields despite the relatively limited area under cultivation. Adequate soil moisture regimes, timely availability of quality inputs and improved crop management practices have contributed to the superior productivity. Therefore, targeted extension interventions are required to promote wider adoption of high-yielding varieties and to concurrently examine the underlying factors responsible for the limited spatial spread of maize cultivation. (Kokilavani and Geethalakshmi, 2013). Area-efficient cropping zones

for maize include Madurai, Tenkasi and Thoothukudi districts. In these districts, maize occupies relatively larger areas; however, productivity remains constrained due to suboptimal agronomic management practices, inadequate availability of quality inputs, the incidence of pest and disease attacks, and adverse climatic factors (Shekhar and Singh, 2022). Chengalpattu, Chennai, Dharmapuri, Kancheepuram, Kanyakumari, Mayiladuthurai, Nagapattinam, Ranipet, Thanjavur, The Nilgiris, Tirupathur, Tiruvallur, Tiruvannamalai, and Tiruvarur are classified as not efficient cropping zones for maize. This indicates that the crop is less suited to the prevailing climatic conditions of these regions. Therefore, alternative crops better adapted to the local agroclimatic conditions are recommended (Abinaya *et al.*, 2022).

Decadal trends for Sorghum in Tamil Nadu

The decadal analysis reveals a marked decline in sorghum area in Tamil Nadu, decreasing from about 714.5 thousand ha during 1965-75 to 280.6 thousand ha in 2005-14, followed by a modest increase to 374.0 thousand ha during 2015-23 (Table 5). In contrast, sorghum productivity showed an overall increasing trend, improving from 732 kg ha⁻¹ in 1965-75 to 1105 kg ha⁻¹ in 2005-14, largely attributable to the adoption of improved varieties and advances in production technologies. The subsequent decline in yield during 2015-23 (1016 kg ha⁻¹) indicates emerging constraints associated with climate variability, moisture stress, and reduced technological adoption, underscoring the need for renewed emphasis on sorghum improvement and targeted support in suitable regions.

Efficient cropping zones - Sorghum

The season-wise classification of efficient cropping zones for sorghum across Tamil Nadu for both kharif and rabi seasons is summarized in Table 3.

Kharif Sorghum: With respect to kharif sorghum in Tamil Nadu, districts such as Dharmapuri, Dindigul, Madurai, Theni, Tirupathur, and Vellore, which exhibit high RSI and RYI, fall under the most efficient cropping zones. The superior performance in these districts can be attributed to the adoption of improved cultivation technologies, use of high-yielding varieties, and more efficient utilisation of available resources (Abinaya *et al.*, 2022). Districts with high RYI and low RSI include Ariyalur, Krishnagiri, Perambalur, Tirunelveli, and

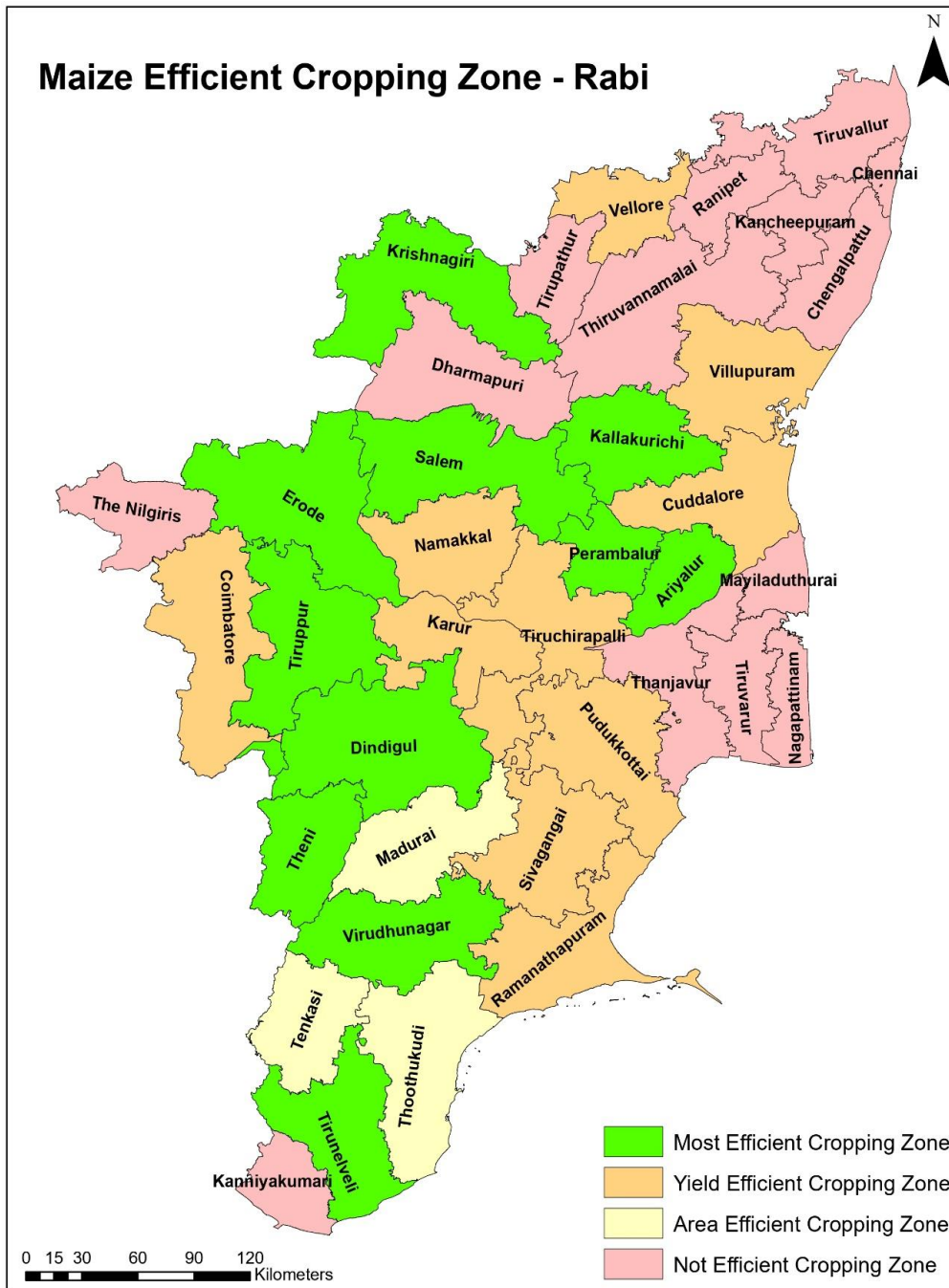


Fig.3. Rabi Maize Efficient Cropping Zones in Tamil Nadu

Table 5. Decadal trend in sorghum area, production, and productivity in Tamil Nadu

Block years	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)	Shift in productivity
1965-66 to 1974-75	714.5	522.1	732	-
1975-76 to 1984-85	725.5	597.8	819	87 (11.9%)
1985-86 to 1994-95	577.5	594.9	1035	216 (26.3%)
1995-96 to 2004-05	362.2	307.4	849	-185 (-17.9%)
2005-06 to 2013-14	280.6	326.5	1105	256 (30.1%)
2015-16 to 2022-23	374.0	386.3	1016	-89 (-8.1%)

Source: Season and Crop Report, 2023-24

Virudhunagar. Suitable soil conditions, availability of quality inputs, access to improved varieties, and favourable climatic conditions have contributed to the higher yields observed in these regions. However, improved extension approaches are needed to promote expansion of the cultivated area in these districts (Bharathi *et al.*, 2020). Area-efficient cropping zones for sorghum include the Coimbatore, Karur, Namakkal,

Salem, Tiruppur, and Tiruchirappalli districts. In these districts, the crop occupies a relatively large share of the cultivated area, but productivity remains moderate or low compared to its potential yield. This indicates that although sorghum is widely grown, there is substantial scope to improve yield through targeted interventions (Sanbagavalli *et al.* 2020). Chengalpattu, Chennai, Cuddalore, Erode, Kallakurichi, Kancheepuram,

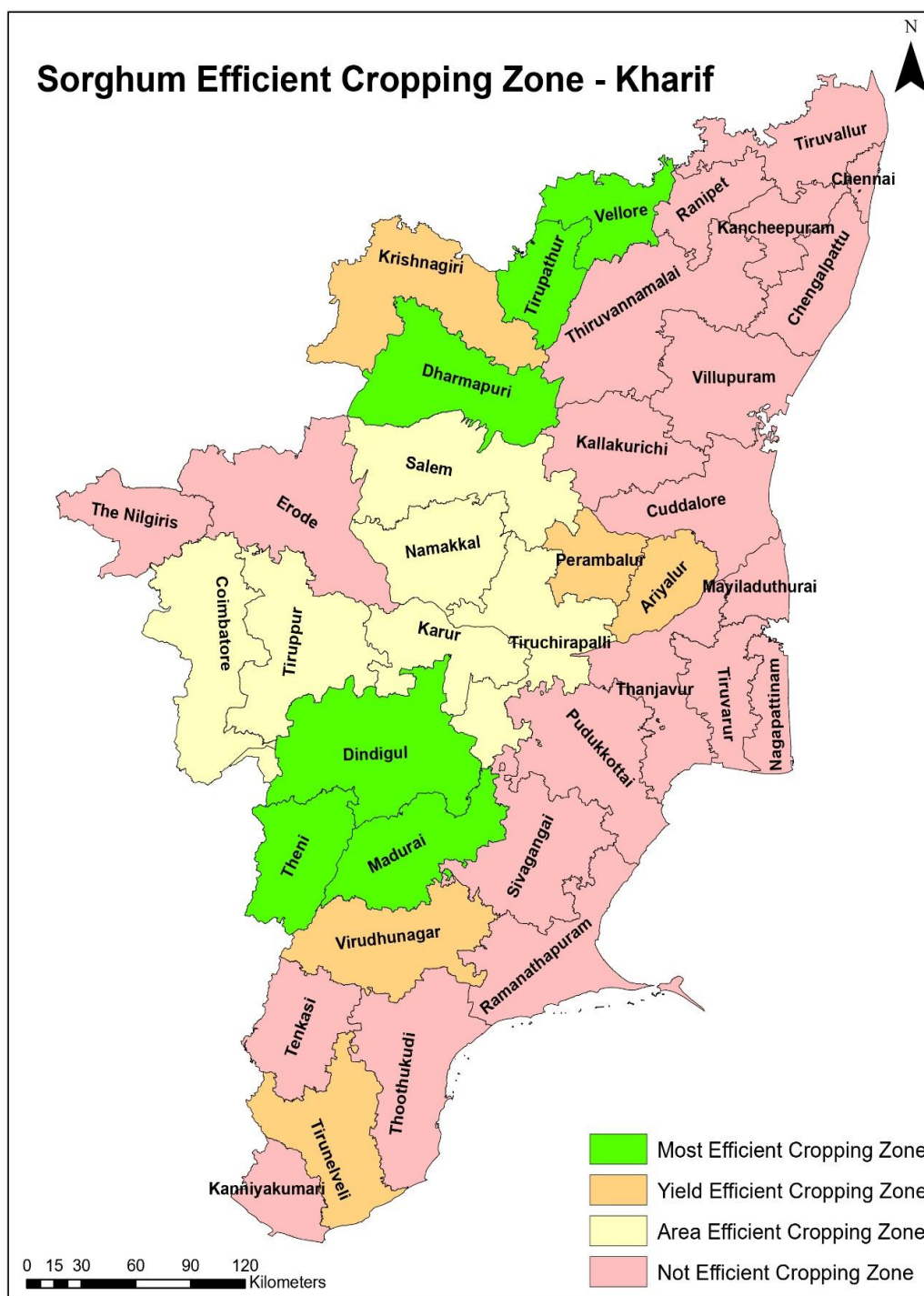


Fig.4. Kharif Sorghum Efficient Cropping Zones in Tamil Nadu

Kanyakumari, Mayiladuthurai, Nagapattinam, Pudukkottai, Ramanathapuram, Sivagangai, Tenkasi, Thanjavur, The Nilgiris, Tiruvallur, Tiruvannamalai, Tiruvarur, Thoothukudi, and Villupuram districts fall under the non-efficient cropping zones for kharif sorghum. The predominance of inefficient kharif sorghum zones in Tamil Nadu is largely attributable to farmers' strategic shift towards relatively high-value and commercially remunerative crops, which have progressively reduced sorghum area and relegated the crop to marginal lands with inherently low yield potential (Praveenkumar *et al.*, 2024).

Rabi Sorghum: The analysis indicated that during the rabi season, six districts in Tamil Nadu, namely Dindigul, Madurai, Theni, Thoothukudi, Tiruchirappalli, and Virudhunagar, were identified as the most efficient cropping zones for sorghum, characterised by relatively higher area concentration and superior yield performance compared with other districts. The superior performance of rabi sorghum in these districts is mainly attributed to favourable residual soil moisture and the availability of supplemental irrigation, together with a stable, conducive rabi-season climate. In addition, long-standing farming experience and higher adoption of improved varieties and recommended crop management practices contribute to greater area concentration and enhanced productivity (Ullah *et al.*, 2022). The districts of Ariyalur, Krishnagiri, Pudukkottai, Ramanathapuram, Sivagangai, Tiruvannamalai, Tirunelveli and Villupuram exhibit high RYI and low RSI; therefore, they are grouped under yield-efficient cropping zones. This indicates that, Area-efficient cropping zones include the while yield potential in these districts is strong, the crop's spatial spread remains limited. As a result, immediate interventions are required to expand the cultivated area. Area-efficient cropping zones include the Coimbatore, Karur, Namakkal, Salem and Tiruppur districts, where productivity remains relatively low, largely due to the continued prevalence of traditional cropping practices and limited adoption of improved crop management methods (Harish *et al.*, 2024). Based on low RSI and RYI values, Chengalpattu, Chennai, Cuddalore, Erode, Kallakurichi, Kancheepuram, Kanyakumari, Mayiladuthurai, Nagapattinam, Perambalur, Ranipet, Tenkasi, Thanjavur, The Nilgiris, Tirupathur, Tiruvallur, Tiruvarur and Vellore were classified as not efficient cropping zones for sorghum, reflecting both low area concentration and poor yield performance. This pattern is consistent with earlier studies on efficient cropping

zones, which have reported a decline in sorghum area, increased competition from alternative crops, and uneven adoption of improved production technologies in Tamil Nadu. (Kokilavani and Dheebakaran, 2019).

Drivers of Area Shift towards Maize in Tamil Nadu

A gradual shift of farmers from cotton and sugarcane towards maize cultivation has been observed in several parts of Tamil Nadu. Cotton cultivation is increasingly constrained by its long duration, high incidence of pest and disease attacks and the requirement for multiple pickings, which raise production costs and labour demand. Similarly, sugarcane occupies land for extended periods, limiting crop rotation and the timely planting of alternative crops. In contrast, maize offers a relatively shorter crop duration, higher productivity, and lower management complexity, making it an attractive alternative for farmers. Although the Minimum Support Price (MSP) for maize is lower than that of some competing crops, its higher yield potential and faster growth provide greater economic viability at the farm level. Consequently, farmers increasingly prefer maize as a flexible, profitable crop.

Comparison of Minimum Support Price Trends for Maize and Sorghum

The Minimum Support Price (MSP) for both maize and sorghum shows a consistent upward trend over the study period, indicating sustained policy emphasis on improving price support for coarse cereals (Figure 6). However, the magnitude and pattern of increase differ between the two crops. Sorghum MSP has increased at a faster rate than maize MSP, particularly after 2018-19, reflecting stronger policy incentives for millets and nutri-cereals. Over the period 2013-14 to 2023-24, sorghum MSP increased from Rs. 1,500 to Rs. 3,180 per quintal, representing an overall rise of about 112%, whereas maize MSP increased from Rs. 1,310 to Rs. 2,090 per quintal, corresponding to an increase of about 60%. A sharp rise in sorghum MSP was observed during 2018-19, coinciding with the national policy shift to ensure MSP is at least 1.5 times the cost of production. In contrast, maize MSP exhibits a more gradual, steady increase over years. Despite the higher MSP and faster growth for sorghum, maize cultivation in Tamil Nadu has expanded more rapidly, driven mainly by strong demand from poultry feed and industrial uses. This divergence suggests that price

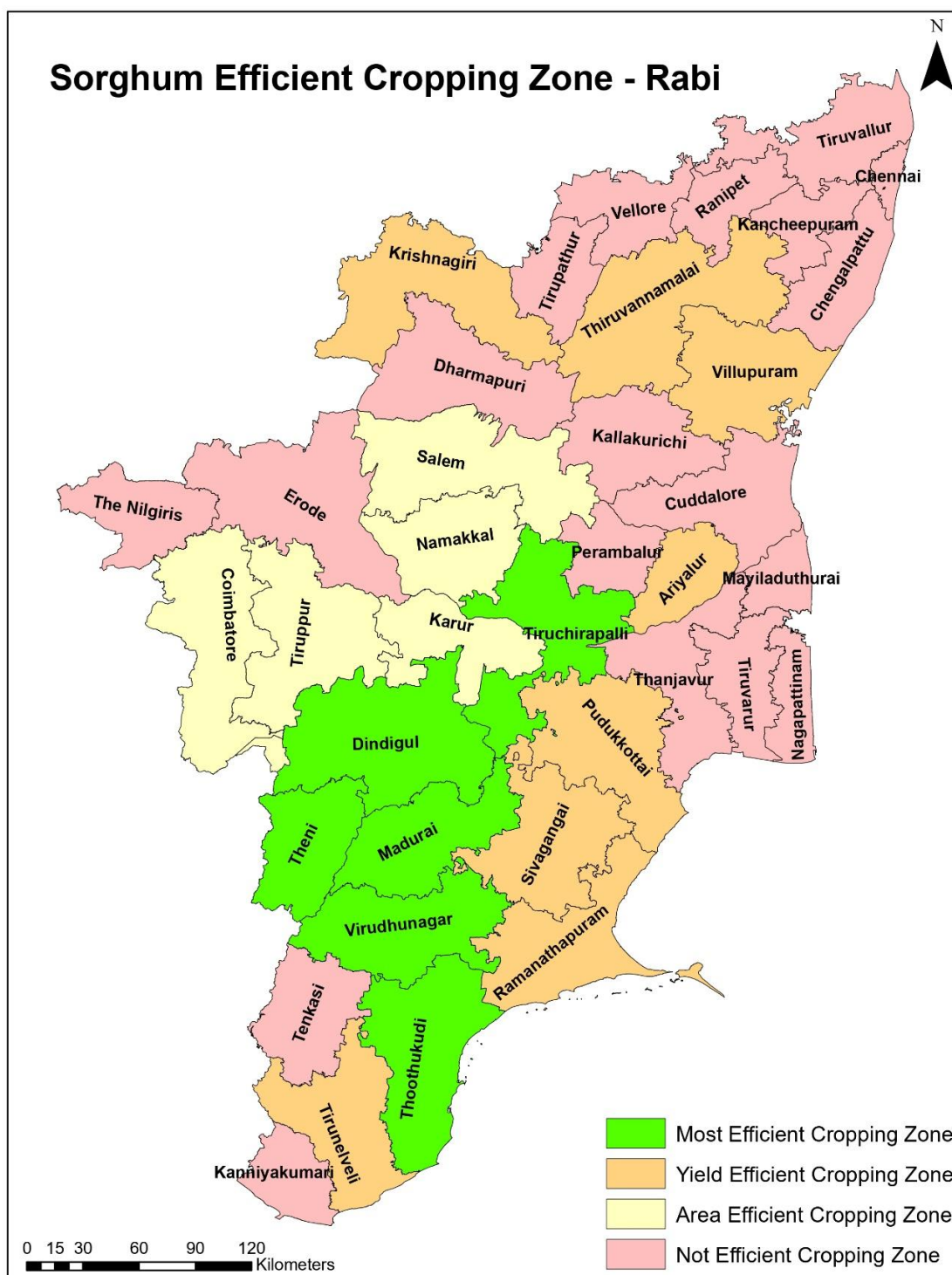


Fig.5. Rabi Sorghum Efficient Cropping Zones in Tamil Nadu

incentives alone are insufficient to induce large-scale area expansion without parallel market development. Therefore, MSP must be complemented by robust value-chain linkages, private-sector participation and localized procurement and processing infrastructure. Such an integrated approach is essential to promote sustained crop diversification, improve farmer profitability and ensure long-term growth of both maize and sorghum in Tamil Nadu.

CONCLUSIONS

The expansion of maize and sorghum in Tamil Nadu is influenced by both price support policies and demand-side market forces, although the relative importance of these drivers differs between the two crops. Maize cultivation is predominantly concentrated in the rabi season, where favourable temperatures,

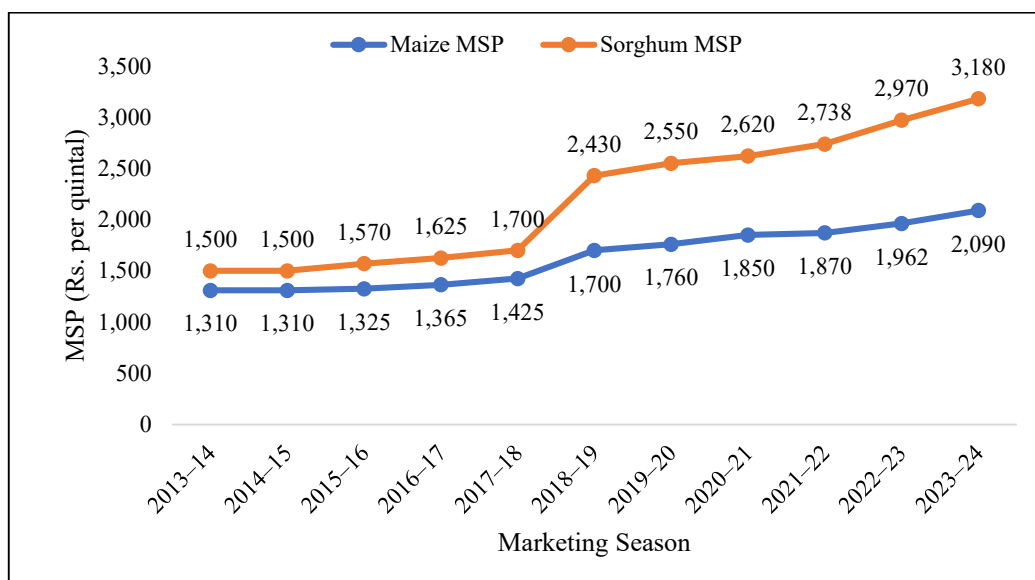


Fig.6. MSP trends for Maize and Sorghum

lower pest incidence, and better irrigation control result in higher and more stable yields. While MSP contributes to income stabilisation for maize farmers, its effect on area expansion remains limited without assured and decentralised procurement. In contrast, strong demand from the ethanol industry and the poultry feed sector, particularly around Namakkal, has played a dominant role in stimulating maize area and production.

Sorghum cultivation, on the other hand, remains largely confined to rainfed and semi-arid regions, where it serves as an important low-input, climate-resilient crop. Despite a relatively higher MSP than maize, sorghum area has continued to decline, reflecting a weak supply response to price incentives alone. Limited MSP procurement, declining consumption, modest productivity gains and the absence of strong industrial demand constrain the expansion of sorghum cultivation.

Overall, the findings indicate that MSP mainly supports income stability, whereas market-linked demand is more effective in driving area expansion. Higher production during the rabi season is primarily attributed to more favourable climatic conditions, reduced biotic stress, and improved irrigation management, which together enhance the yield stability compared to the kharif season. Therefore, strengthening MSP-backed local procurement, promoting value-added uses for food and feed, developing processing and marketing infrastructure, and providing targeted extension support are essential

to enhance productivity and ensure the sustainable growth of both maize and sorghum in Tamil Nadu.

Tamil Nadu Government Initiatives for Promoting Millet-Based Cropping Systems

The Government of Tamil Nadu has implemented several policy initiatives to promote millet-based cropping systems as part of its broader strategy for climate-resilient agriculture, nutritional security, and sustainable livelihoods. A major intervention is the Tamil Nadu Millet Mission (2023-24 to 2027-28), which seeks to enhance millet area, productivity, value addition and consumption, particularly in rainfed and dryland regions. The programme supports both major and minor millets through the timely supply of quality seed, the dissemination of improved production practices, the establishment of processing infrastructure and the strengthening of market linkages. Further, convergence with schemes such as Nutri-Cereals, Promotion of Millets under National Agricultural Development Programme, Common Facilitation Centres and Kalaigarnar’s All Village Integrated Agricultural Development Programme has reinforced input supply, processing, and marketing support. Collectively, these initiatives provide a strong institutional framework for revitalising millet cultivation and improving the livelihoods of dryland farmers in Tamil Nadu.

Recognising maize as a strategic crop for food, feed and biofuel security, the Government of Tamil

Nadu has accorded special emphasis to maize from 2024-25 onwards to enhance its area, production and productivity. Promotion is primarily implemented through the food and nutrition security-coarse cereals programme and the National Agricultural Development Programme (NADP), with large-scale demonstrations involving hybrid seeds, organic inputs and improved agronomic practices. These interventions have covered about 1.03 lakh ha with an outlay of ₹68 crore and have improved farm-level profitability, as maize exhibits a higher cost-benefit ratio than paddy and cotton.

Market-oriented interventions include the establishment of a maize market promotion centre at Thozhudur (Cuddalore district), with a cattle feed pelleting unit and a maize cum millet value addition unit at Perambalur, during 2025-26 to promote local processing and value addition. Proposed measures further focus on assured procurement at regulated markets and farm gate level, creation of common drying yards and storage godowns, installation of solar dryers to maintain grain moisture below 12%, promotion of end-to-end mechanisation, facilitation of e-NAM-based marketing, strengthening of farmers FPO linkages with poultry and ethanol industries. Together, these initiatives aim to build a resilient, market-linked production system for millets in Tamil Nadu.

POLICY IMPLICATIONS AND RECOMMENDATIONS

Evidence from district-level studies in Tamil Nadu indicates that maize cultivation is economically viable but constrained by weak price transmission, limited market infrastructure, and uneven access to quality inputs. Although MSP provides an important price signal, many farmers are either unaware of it or receive prices below the announced level. This highlights the need to strengthen decentralised procurement systems, farmer awareness programmes, and village-level facilities such as drying yards and storage structures. The relative expansion of Rabi maize over Kharif maize reflects its lower production risk and more stable yields under Tamil Nadu conditions, supported by better soil moisture availability, suitable temperatures and greater scope for irrigation and nutrient management. Policy should prioritise the promotion of rabi and irrigated maize through the timely supply of quality seed, the expansion of irrigation infrastructure, and the dissemination of improved crop management practices. At the same time, risks in kharif maize can be reduced through the adoption of

climate-resilient hybrids and weather-based advisories. Strengthening farmer aggregation through Farmer Producer Organisations, promoting mechanisation via custom hiring centres, and facilitating direct linkages with poultry feed and industrial users are essential to enhance price realisation and profitability.

Despite a higher MSP than maize, the sorghum area in Tamil Nadu remains low due to weak MSP transmission, poor market demand, low profitability, and limited industrial utilisation. Long-term trends indicate a persistent decline in sorghum area and production, while maize exhibits strong positive growth driven by feed and industrial demand. Strengthening decentralised MSP procurement, integrating sorghum into PDS and nutrition schemes and promoting sorghum-based industrial and feed uses are essential to reverse the declining trend. In addition, an investigation on rabi sorghum varietal improvement and value addition is required to enhance sorghum production in Tamil Nadu.

ACKNOWLEDGEMENT

The authors sincerely acknowledge the Special Programme Implementation Department, Government of Tamil Nadu, for facilitating the Tamil Nadu Chief Minister's Fellowship Programme (2024-2026). The authors also express their gratitude to the Department of Agriculture - Farmers Welfare, Government of Tamil Nadu, for providing technical and dataset support, and to the Bharathidasan Institute of Management, Thiruchirappalli, for their guidance and academic support as the academic partner.

DECLARATIONS

Author's contribution:

Ammaiyappan A: Conceptualization, methodology development and drafting the initial manuscript; Data curation, analysis, and visualization

Sharuk Khan M: Data Visualization and editing

Sujitha P: Review and editing

Mahalingam D : Overall Supervision, Critical review and technical inputs.

Funding

No Funding was received for this study

Ethical Approval

This study does not involve human or animal subjects; therefore, ethical approval is not applicable.



Consent to Participate

Not applicable, as no human participants were involved. Consent to Publish Not applicable, as no human participants were involved.

Competing Interests

The authors declare no competing interests.

Data Availability Statement

Data on area under cultivation, production, productivity, and total cultivable area of maize and sorghum for both kharif and rabi seasons (2013-14 to 2023-24) were obtained from the respective year, season, and Crop Report, Directorate of Economics and Statistics, Government of Tamil Nadu.

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