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RESEARCH ARTICLE

Crop diversification and water-efficient irrigation: Insights from the TNIAMP initiative in the Cauvery Delta sub-basin

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Abstract

The Cauvery Delta, historically known as the "Granary of Peninsular India," is crucial for Tamil Nadu's agriculture but faces growing challenges from water scarcity, salinity and climate change. The water-intensive rice cultivation in the region needs an alternative crop to minimize the water requirement. This study examines maize as a viable crop under the Tamil Nadu Irrigated Agriculture Modernisation Project (TNIAMP). Maize requires less water, has shorter cultivation cycles and offers higher profitability, achieving an average yield of 5497 kg and a benefit-cost (B:C) ratio of 1.76 for dry seed production. To promote diversification, maize was demonstrated across 5000 ha using improved technologies like nutrient and pest management. Results show fresh cob production is particularly profitable, with a B:C ratio of 2.68 compared to 1.06 for paddy. Diversification indices, including the Herfindahl Index (HI) and Entropy Index (EI), reveal a positive shift toward diversified cropping patterns since 2017 due to maize adoption. These trends mitigate risks associated with monocropping and improve resilience to environmental challenges. Although challenges such as groundwater salinity and erratic water supply persist, targeted interventions such as farmer training, improved irrigation practices and institutional support have facilitated a steady increase in maize cultivation across Thanjavur, Thiruvarur and Nagapattinam districts. The study highlights maize's potential to address water scarcity while enhancing agricultural sustainability and farmer livelihoods. This research emphasizes the importance of maize in balancing efficiency and diversity in cropping systems, advocating for continued institutional support, adaptive strategies and farmer-centric policies to ensure long-term sustainability. By integrating economic and environmental benefits, this study offers actionable insights for policymakers and stakeholders seeking to mitigate climate challenges and secure agricultural resilience in the Cauvery Delta.

Keywords: crop diversification indices; economic analysis; irrigation; maize; paddy

Introduction

The Cauvery Delta, located in Tamil Nadu, is an alluvial tract shaped by the Cauvery River and covers an area of 6.9 lakh ha of delta (1). Historically known as the "Granary of Peninsular India," it contributes 25 % of the state's rice production and houses Tamil Nadu's largest irrigation system (1). Fig. 1 illustrates the Cauvery Delta sub-basin, which spans 14.47 lakh ha, with the former Thanjavur district (now divided into Thanjavur, Thiruvarur and Nagapattinam) accounting for 57 % of the total area. Agriculture has been the backbone of the delta, supported by monsoon rains and seasonal floods. Table 1 shows the crops cultivated in this basin, rice is cultivated as a single or double crop in 6.1 lakh ha, dominates the landscape, followed by pulses, vegetables and oilseeds. Other crops, including groundnut, maize and irrigated pulses are grown in garden lands, while coconut, banana, sugarcane and fruit trees like mango and guava are cultivated. However, the region faces growing challenges due to water scarcity and an over-reliance on paddy, which has led to the exploration of crop diversification to improve water use efficiency and sustainability.

The TNIAMP has introduced maize as a promising alternative crop, offering higher yields, reduced water consumption and enhanced pest resilience. Maize, with an average yield of 5497 kg/ha and a B:C ratio of 1.76, has gained popularity, particularly during the water-scarce kuruvai season (popularly called as short duration paddy cultivation season, June-September with the onset of southwest monsoon) (1). To encourage crop diversification, TNIAMP has implemented Improved Production Technology (IPT) demonstrations on 5000 ha, utilizing high-quality seeds and integrated technologies, including nutrient and pest management as well as drought mitigation. A pilot project funded by the World Bank demonstrated the potential of maize cultivation across 300 acres in Thanjavur, Thiruvarur and Nagapattinam, proving it as a profitable and water-efficient alternative to paddy.

Despite these initiatives, several challenges remain, particularly in Thanjavur and Thiruvarur, where rising groundwater salinity, inadequate irrigation and delayed water releases from the Mettur Reservoir are significant concerns. Over-extraction of

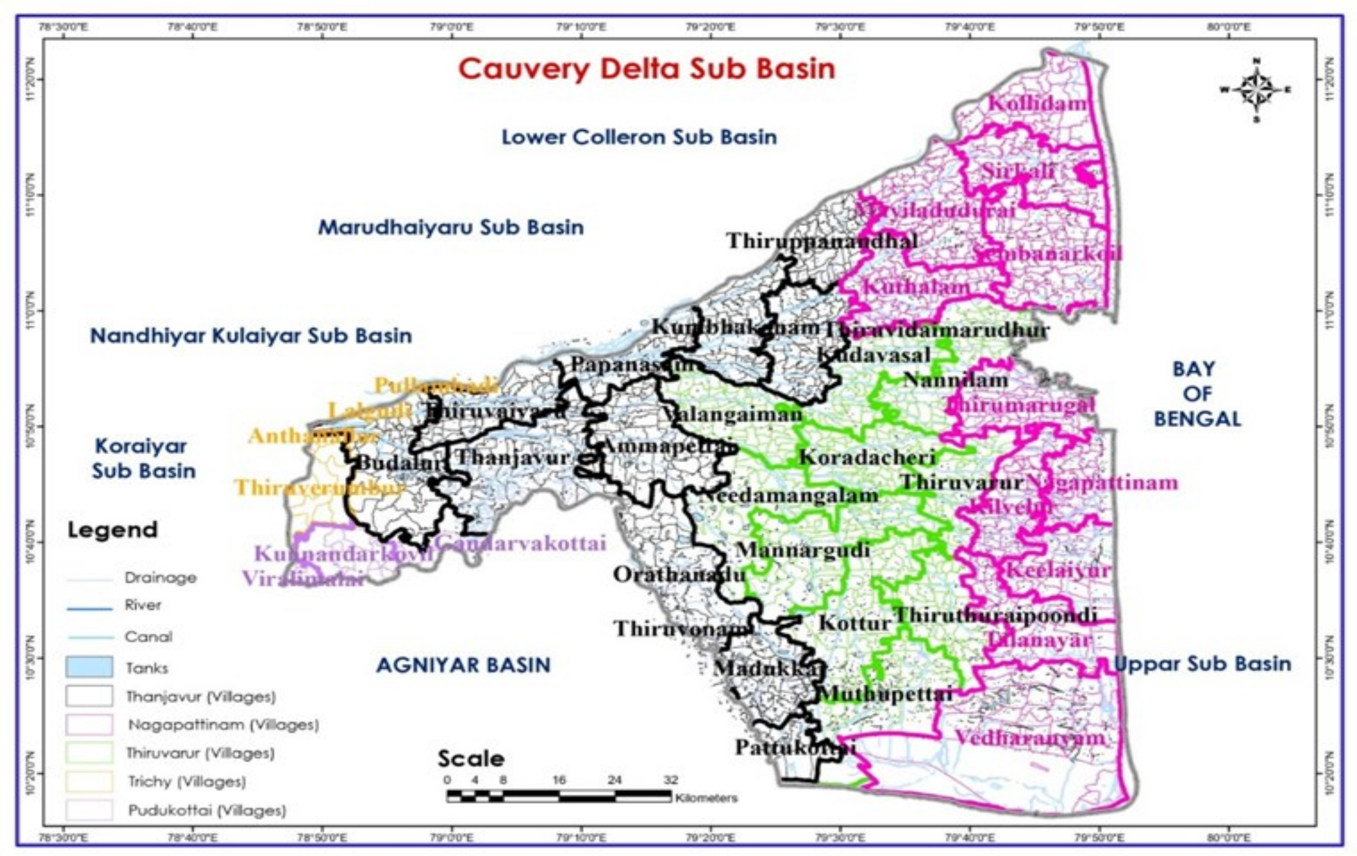

Fig. 1. Map of the Cauvery Delta sub-basin.

Table 1. Major agricultural crops in the Cauvery Delta districts of Tamil Nadu

Districts	Agricultural crops
Thanjavur	Paddy, Groundnut, Sugarcane, Gingelly, Maize
Thiruvarur	Paddy, Black gram, Green gram, Groundnut, Ginegelly, Arecanut, Coconut, Tamarind
Nagapattinam	Paddy, Black gram, Green gram, Sugarcane, Groundnut, Maize, Mango, Banana, Cashew

(Source: Climate Change Information Portal, Climate Studio, Anna University, Tamil Nadu)

groundwater has worsened salinity, affecting core delta areas, while erratic rainfall and climate change further complicate water availability. These issues have led many farmers to skip the kuruvai crop or leave land fallow, with some proposing the removal of kuruvai from the farming calendar to conserve water for the samba season (August to January) (2).

In response, TNIAMP has initiated maize cultivation trials on 175 ha in Thiruvarur and Nagapattinam, promoting crop diversification to reduce water use and increase cropping intensity. However, challenges such as erratic surface water availability, escalating groundwater salinity and insufficient rainfall continue to threaten the region's agricultural sustainability. The region's reliance on the Cauvery Delta System, Lower Coleroon Anicut System and the Cauvery Mettur Project is also under pressure from drainage problems, salinity and flooding; all of which pose risks to long-term agricultural viability (3, 4). This study investigates the growing trend of crop diversification in the Cauvery Delta, particularly the shift from paddy to maize and assesses its potential to mitigate water scarcity and environmental challenges.

Paddy vs. maize - State at a glance

Agricultural production statistics in Tamil Nadu present a compelling comparison between paddy and maize, offering a clear statewide overview. Tamil Nadu's paddy cultivation area over the past two decades (2004–2024) exhibited a decline by 19.36 %; compared to the average area cultivated in the preceding five decades (1954-2004) (Fig. 2 & 3). However, there has been an increase in paddy production by about 22.17 % in the past two decades compared to the previous five decades, due to interventions in improved cultivation technologies. The analysis of maize statistics for the same period (average of the past two decades, 2004–2024 vs. the average of the previous five decades, 1954–2004) shows an 889.64 % increase in maize cultivation area and a 2695.96 % increase in maize production. Over the past two decades, paddy cultivation area has declined by 369825 ha, whereas maize has expanded by 215724 ha, likely driven by its lower water requirement and higher economic returns.

According to agricultural statistics, paddy production dropped by more than 50 % between 2015–2016 and 2016–2017. This correlates with the crop coverage data, which fell from 12.7 lakh ha in 2015–2016 to 7.4 lakh ha in 2016–2017, a 41.5 % decrease, according to Union Government statistics (5).

Suitability of delta for maize

The perusal of rice crop area and productivity data revealed that the Most Efficient Cropping Zone (MECZ), which has a high Relative Spread Index (RSI) and high Relative Yield Index (RYI) for rice, is located in the Thanjavur, Thiruvarur and Nagapattinam districts of Tamil Nadu. The rice crop can establish well with an amble water source during the crop growing period and the spread of the crop within the farming community is more prevalent in these districts since these areas are situated in and around river basins (6).

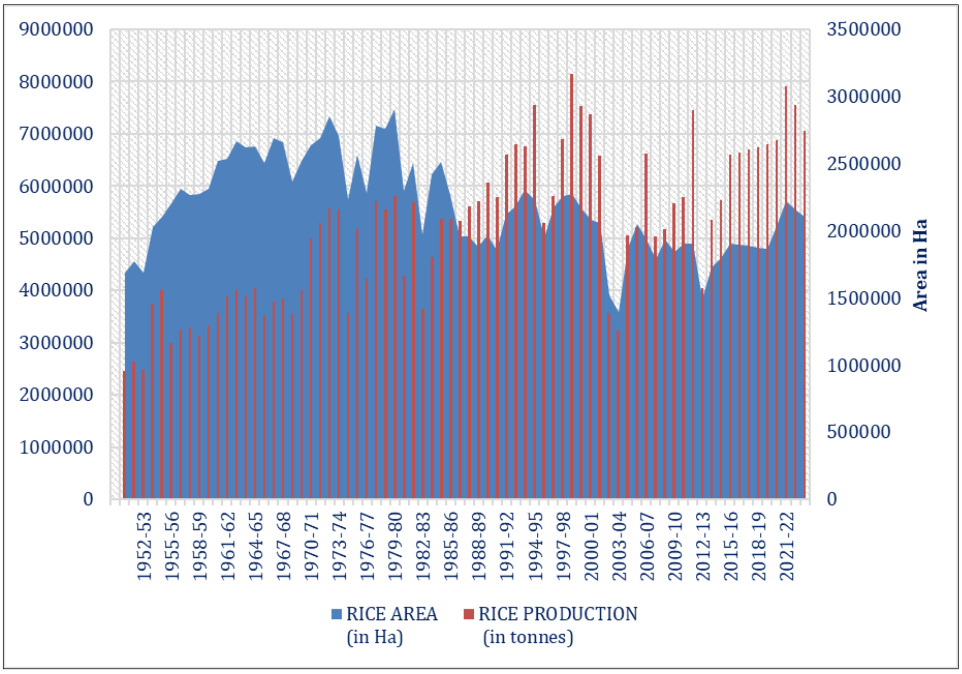

Fig. 2. Decadal trend in rice cultivation area and production in Tamil Nadu.

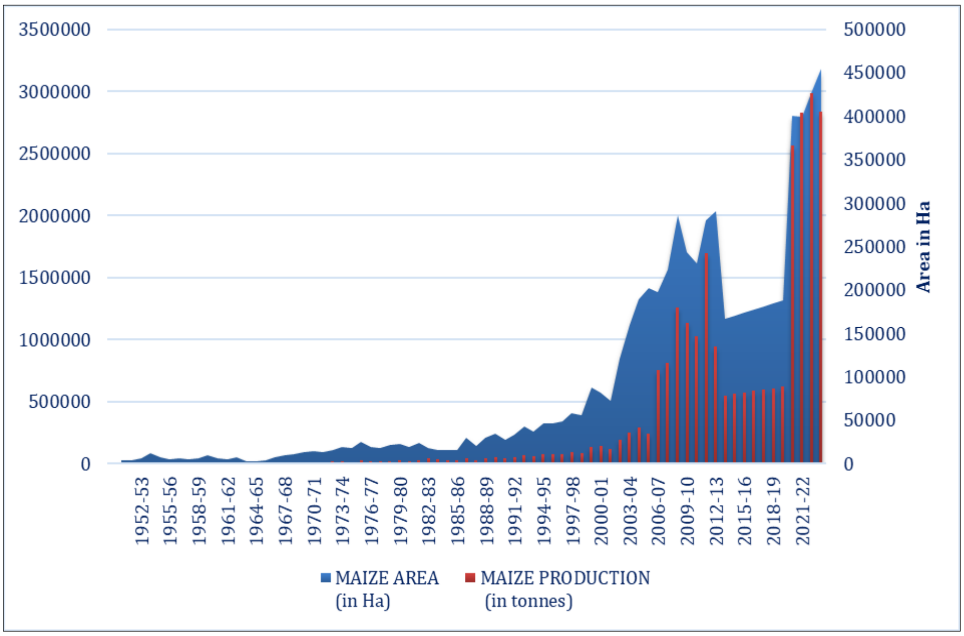

Fig. 3. Decadal trend in maize cultivation area and production in Tamil Nadu.

Maize is highly sensitive to both excessive moisture and moisture stress, requiring optimal water levels throughout its growth stages. With high RYI and low RSI values, Thanjavur district falls under the Efficient Cropping Zone (ECZ) (Table 2). The yield of the crop in this region is high and hence, the crop may be promoted through better extension methodologies or the reasons for the low spread may be examined. Nagapattinam and Thiruvarur districts fall under the Highly Inefficient Cropping Zone (6).

To address the need for alternative crops, TNIAMP funded by the World Bank, facilitated a demonstration of maize as a substitute for kuruvai paddy across 2736 acres in Nagapattinam, Thanjavur and Thiruvarur districts. The initiative led by the State Department of Agriculture and Tamil Nadu Agricultural University (TNAU) promoted best agronomic practices including application of 12.5 t/ha of farmyard manure (FYM) and 10 packets of *Azospirillum*, biofertilizer and proper field preparation with ploughing and compost spreading. Ridges and furrows were formed for irrigation and fertilizers were applied as per recommended doses. A seed rate of 20 kg/ha was used, with plants spaced 25 cm apart in rows. Weed management involved pre-emergence atrazine application and hand weeding, while thinning and gap filling were done 12-15 days after sowing (DAS). Top dressing of nitrogen was applied in two stages: on the 25th and 45th DAS.

Table 2. ECZ of rice and maize in Cauvery Delta sub-basin of Tamil Nadu

District	Rice			Maize		
	RSI	RYI		RSI	RYI	
Thanjavur	H	H	ME	L	H	E
Thiruvarur	H	L	NE	L	L	HIE
Nagapattinam	H	L	NE	L	L	HIE

(RSI: Relative Spread Index; RYI: Relative Yield Index; H: High; L: Low; ME: Most Efficient; E: Efficient; NE: Not Efficient; HIE-Highly Inefficient Zone)

Materials and Methods

Measuring crop diversification

To assess crop diversification, the Crop Diversification Index (CDI) was employed (7, 8). The CDI reflects the degree of diversification, with a zero-value indicating specialization and values greater than zero signifying diversification (9). This enabled the identification of farmers practicing diversification.

Horizontal indices

a) Herfindahl Index (HI)- Measures evenness in land distribution among crops.

$$HI = \sum_{i=1}^{n} Pi^2 \quad \text{(Eqn. 1)}$$

$$P_i = \frac{\text{Area of crop i}}{\text{Total cropped area}} \quad \text{(Eqn. 2)}$$

Where,

n = total number of crops

P_i = proportion of i_{th} crop

b) Transformed Herfindahl Index (THI)- Adjusted version of HI for better interpretability.

THI: The THI is expressed as:

$$THI = 1 - HI \quad \text{(Eqn. 3)}$$

c) Entropy Index (EI)- Evaluates distribution diversity across crops. EI is an inverse measure of concentration and has been widely used to measure diversification.

The formula for computing EI is as

$$EI = \sum_{i=1}^{N} Pi \ln(P_i) \quad \text{(Eqn. 4)}$$

Where,

P_i = Proportion of the area occupied by the i_{th} crop

N = Total number of crops

ln = Natural logarithm

Vertical Indices

a) Ogive Index (OI)- Measures inequality or dominance among crops.

$$OI = \sqrt{\frac{\sum_{i=1}^{n}\left(p_i - \frac{1}{n}\right)^2}{n-1}} \quad \text{(Eqn. 5)}$$

Where,

P_i = Proportion of the area occupied by the i_{th} crop

n = Total number of crops

b) Bhatia's method- Evaluates concentration by ranking crops based on area or value. In this study, we used two crops common in smallholder farming in Cauvery Delta sub-basin to calculate the index. The two crops included maize and rice. On rice, the household considered rice growers were the ones growing at least two seasons in a year.

$$CI = \sum_{i=1}^{n}\left(\frac{A_i}{A}\right) R_i \quad \text{(Eqn. 6)}$$

Where,

A_i = Area under the i^{th} crop

A = Total cropped area

R_i = Rank of the i_{th} crop (highest area = rank 1)

c) Lorenz curve and Gini index- Visualizes and quantifies inequality in crop shares.

Lorenz curve:

1. Arrange crops in ascending order based on their proportion of total cropped area.
2. Calculate the cumulative percentage of crops and cropped area.
3. Plot the cumulative percentage of cropped area (Y-axis) against the cumulative percentage of crops (X-axis).
4. Compare the curve with the line of equality (a 45 ° diagonal line). Greater deviation from the diagonal indicates more inequality.

Gini index:

The Gini index quantifies the degree of inequality as a single value derived from the Lorenz curve. It is calculated as the ratio of the area between the Lorenz curve and the line of equality to the total area under the line of equality.

$$G = 1 - \sum_{i=1}^{n} (P_{i-1} + P_i)(Q_i - Q_{i-1}) \quad \text{(Eqn. 7)}$$

Where,

P_i = Cumulative proportion of crops

Q_i = Cumulative proportion of cropped area

n = Total number of crops

G= Gini index

Results and Discussion

Economic analysis

The economic analysis of paddy and maize production under the TN-IAM Project shows notable differences in profitability and efficiency across the two crops (Table 3). For paddy, the yield stands at 6631 kg/ha, with a cost of cultivation of ₹62942, resulting in a gross income of ₹120348 and a net income of ₹57406. However, the B:C ratio for paddy is only 1.06, indicating limited profitability, as the returns are marginally higher than the investment. In contrast, maize production demonstrates greater economic viability, particularly for fresh cob production. Maize yields 4988 kg/ha for dry seed production or 30818 cobs for fresh cob production. The cost of cultivation for maize is lower (₹56682 for dry seed production) and significantly lower at ₹30998 (for fresh cob production). The gross income for fresh cob production

Table 3. Economic analysis for one hectare paddy vs. maize production from the TNIAM Project

Crop	Yield		Cost of cultivation		Gross income		Net income		BC ratio	
	kg	Cobs	Dry seed production	Fresh cob production	Dry seed production	Fresh cob production	Dry seed production	Fresh cob production	Dry seed production	Fresh cob production
Paddy	6631	-	62942	-	120348	-	57406	-	1.06	-
Maize	4988	56682	30818	30998	84800	113364	53983	82366	1.77	2.68

is ₹113364 while for dry seed production, it is ₹84800. This results in a net income of ₹53983 for dry seed production and ₹82366 for fresh cob production. Notably, the BC ratio for maize is substantially higher 1.77 for dry seed production and 2.68 for fresh cob production indicating much better returns on investment compared to paddy. This is due to low input costs and high yield efficiency coupled with strong market demand for maize. In global level around 60 % of maize is used by poultry feed sector. Short duration, quick marketability and consumer preference contribute to its profitability. Similar findings highlighting that diversification into maize cultivation can help farmers mitigate risks associated with paddy production, including crop failures caused by floods, droughts and pest or disease outbreaks (10).

Overall, maize fresh cob production emerges as the most profitable and efficient option, offering the highest net income and economic returns, making it a more favourable choice for farmers under the TNIAM Project guidelines (11).

Crop diversification

Traditionally farmers prefer to choose paddy in one or two seasons wherever the assured water is available.

In the project area, the initiative aims to promote crop diversification by encouraging the cultivation of low water-requiring and higher remunerative crops like millets, maize, pulses, oilseeds, vegetables, fruits and flowers, enhancing climate resilience. Crop diversification is also primarily attended towards reducing greenhouse gas emission and thereby increasing carbon sequestration (12). Crop diversification ensures food security for the under privileged.

Crop diversification indices

Crop diversification indices are used to measure the distribution and concentration of crops grown in a region. These indices assess how evenly different crops are cultivated, indicating the level of diversity in agricultural practices. Farmers in the Cauvery delta sub-basin are diversifying crops to improve the sustainability of agriculture, optimize resource use and mitigate risks associated with monocropping, such as dependency on water-intensive crops and vulnerability to market fluctuations. However, they face notable challenges, including delayed release of Cauvery water, reduced water availability and climatic uncertainties (13). To address these challenges, initiatives under the TNIAMP, led by TNAU and the State Department of Agriculture, Tamil Nadu, have focused on diversifying cropping patterns, with an emphasis on maize cultivation due to its lower water requirement. Table 4 presents a detailed index-wise analysis of the trends in crop diversification under TNIAMP.

The horizontal and vertical indices provide a comprehensive view of crop diversification trends over the study period, reflecting the effects of institutional interventions, climatic challenges and farmer preferences.

Horizontal indices

HI: The HI serves as a key indicator of crop concentration, where lower values indicate greater diversification. The results reveal a dynamic evolution in cropping patterns. From 2007-08 to 2013-14, the HI remained relatively low (0.35-0.39), suggesting that farmers maintained diverse cropping systems during this period. This could be attributed to the absence of strong policy direction and the continued reliance on traditional crop choices to mitigate risks associated with environmental variability. However, after 2017-18, the HI rose significantly to 0.51 by 2023-24, signalling a growing concentration of cropping systems.

This trend aligns with the deliberate promotion of maize cultivation under TNIAMP as a sustainable alternative to water-intensive crops like paddy. Institutional support for maize cultivation, including demonstrations, subsidies and capacity-building initiatives, likely influenced farmers to allocate a larger share of their land to this crop, reducing overall diversification.

Similar findings found that decline in crop diversity in Punjab due to government support for rice-wheat systems, which reduced the cultivation of minor cereals and pulses (14). In the context of Tamil Nadu, policy-driven promotion of maize has reinforced its dominance in cropping systems, reflecting the trends observed in this study (15).

THI: The THI, which is inversely related to HI, highlights the reduction in diversification over time. From 0.65 in 2007-08 to 0.49 in 2023-24, the THI values underscore a narrowing focus on fewer crops. This shift reflects the increasing dominance of maize in response to water scarcity and its economic viability compared to paddy. While the trend demonstrates the success of targeted interventions in encouraging specific cropping patterns, it also raises concerns about the long-term risks of reduced crop diversity, such as vulnerability to market fluctuations and pest outbreaks.

Table 4. Crop diversification indices of Cauvery delta sub-basin from 2007–08 to 2023–24

Year	Indices					
	Horizontal				Vertical	
	HI	THI	EI	OI	Bhatia's method	Lorenz curve & Gini
2007–08	0.35	0.65	1.00	0.16	1.00	1.00
2008–09	0.43	0.57	0.87	0.18	0.89	0.93
2009–10	0.42	0.58	0.87	0.18	0.88	0.94
2010–11	0.41	0.59	0.87	0.17	0.87	0.95
2011–12	0.44	0.56	0.85	0.18	0.86	0.93
2012–13	0.49	0.51	0.80	0.19	0.86	0.88
2013–14	0.39	0.61	0.91	0.17	0.92	0.97
2014–15	0.41	0.59	0.89	0.17	0.91	0.96
2015–16	0.42	0.58	0.87	0.18	0.89	0.96
2016–17	0.45	0.55	0.84	0.18	0.87	0.92
Introduction of TNIAMP (2017–18)						
2017 - 18	0.43	0.57	0.86	0.18	0.88	0.95
2018 - 19	0.45	0.55	0.85	0.18	0.88	0.93
2019 - 20	0.44	0.56	0.86	0.18	0.89	0.95
2020 - 21	0.49	0.51	0.81	0.19	0.88	0.91
2021 - 22	0.47	0.53	0.85	0.19	0.91	0.93
2022 - 23	0.46	0.54	0.86	0.19	0.91	0.94
2023 - 24	0.51	0.49	0.81	0.20	0.90	0.91

The decline in the THI over time suggests reduced diversification, promotion of high-yielding crops like maize and wheat under state programs often leads to monoculture systems, reducing the overall diversity of cropping patterns (16).

EI: The EI, a measure of evenness in crop distribution, provides additional insights into diversification trends. During the early years (2007 - 08), the EI peaked at 1.00, indicating a high degree of diversity. However, the index declined to 0.80 by 2012 - 13, reflecting a gradual concentration of cropping systems. Interestingly, the EI rebounded slightly in recent years, increasing of index value 0.87 in 2019 - 20 to 0.88 in 2022 - 23. This improvement highlights the impact of promoting drought-resistant crops like maize while still maintaining some level of diversity. The index suggests a more balanced approach in recent years, where diversification was not entirely sacrificed despite the dominance of maize. A similar recovery was observed in EI in parts of Odisha after introducing maize and millets under government programs aimed at combating water scarcity (17).

Vertical indices

OI: The OI reveals the meagre changes in crop inequality over time. While the index remained relatively stable, it showed a slight increase post-2017 - 18, rising from 0.18 to 0.20 in 2023 - 24. This uptick reflects growing disparities in land allocation among crops, with maize and paddy occupying larger shares of the cropped area. The increase in OI underscores the concentration trend observed in horizontal indices, further reinforcing the strategic focus on maize as a preferred crop.

This trend is consistent with findings which report growing inequality in land allocation in Eastern India resulting from the dominance of rice and maize in irrigated regions (18). The findings suggest that while introducing high-value crops is beneficial, it may inadvertently increase disparities in land use.

Bhatia's method: Bhatia's method provides a ranking-based perspective on crop concentration. The values fluctuated modestly, declining of index value from 1.00 in 2007–08 to 0.95 in 2023–24. These minor variations highlight a balanced approach to crop promotion under TNIAMP. While maize emerged as a dominant crop, traditional crops like coconut and banana retained their significance, ensuring some level of diversification. The results suggest that policy interventions were successful in promoting maize without completely overshadowing other important crops.

Bhatia's method indicated a balanced promotion of crops, with maize gaining prominence, crops like coconut and banana remained significant. This observation aligns with a previous study that found government initiatives promoting crop diversification crops due to their cultural and economic significance, ensuring that farmers have a mix of risk-reducing and income-enhancing options (19).

Lorenz curve and Gini index: The Lorenz curve and Gini index provide a graphical and quantitative analysis of inequality in crop distribution. The Gini index remained high throughout the study period, with values starting at 1 in 2007–08 and declining slightly to 0.91 in 2023–24. The persistently high values indicate substantial dominance by a few crops, particularly paddy and maize, even after the introduction of TNIAMP. The slight decline suggests a marginal improvement in diversification, likely due to efforts to encourage alternative crops like maize.

This finding is corroborated by the high Gini coefficients observed in West Bengal, which are attributed to the concentration of rice cultivation (20). The slight improvement in the Gini Index observed in this study indicates that diversification efforts, though limited, have contributed to marginally reducing inequality.

Insights from the indices

The horizontal indices demonstrate a clear shift toward concentration, driven by the strategic promotion of maize. This trend aligns with the objectives of TNIAMP, which aimed to address water scarcity and enhance agricultural profitability by encouraging less water-intensive crops. The vertical indices complement these findings, revealing increased inequality in crop distribution but also indicating that traditional crops retained some prominence.

While the stabilization of cropping patterns reflects the success of targeted interventions, the reduced diversity poses potential risks especially production risk. Dependency on a narrower range of crops may increase vulnerability to market and climatic uncertainties. Moving forward, policies should aim to strike a balance between promoting economically and environmentally sustainable crops like maize while maintaining sufficient diversification to ensure resilience and long-term agricultural sustainability.

Promotion of maize production in sub-basins

In the river basins, maize is primarily grown using traditional varieties. The initiative now aims in transition toward hybrid maize to enhance yield potential through the adoption of IPT. Demonstrations will be conducted to showcase best practices and suggest suitable interventions. The demonstration includes applying 12.5 t/ha of farmyard manure (FYM) along with 10 packets of *Azospirillum* (2000 g/ha), which are evenly distributed on unploughed fields and incorporated into the soil to enhance microbial activity and soil fertility. Ridges and furrows, 6 m long and 60 cm apart, are formed, with sufficient irrigation channels. Fertilizer application follows a recommended NPK dose of 135:62.5:50 kg/ha, with a quarter of nitrogen (N) and full doses of phosphorus (P) and potassium (K) applied basally, along with micronutrients. A seed rate of 20 kg/ha is adopted, with a spacing of 25 cm between plants in 60 cm apart rows. Weed management includes pre-emergence application of atrazine (0.25 kg/ha) on 3-5 DAS, followed by one hand weeding at 30-35 DAS. Thinning and gap filling are performed 12-15 DAS, leaving only one healthy seedling per hole and filling gaps with pre-soaked seeds. Top dressing with nitrogen involves applying half the N dose on the 25th day and the remaining quarter on the 45th day, covered with soil.

Maize cultivation area in Cauvery delta sub-basin

Fig. 4 highlights the trends in maize cultivation across the districts of Thanjavur, Thiruvarur and Nagapattinam in the Cauvery Delta sub-basin from 2017-18 to 2023-24. The data illustrates the impact of targeted interventions, including those implemented under the TNIAMP project, in promoting maize cultivation as a viable alternative to water-intensive crops like paddy.

In Thanjavur, maize cultivation witnessed a steady rise from 1250 ha in 2017-18 to 6884 ha in 2023-24. This consistent increase reflects the effectiveness of project interventions such as capacity-building programs, farmer training and awareness campaigns. Thanjavur district is located at the head of the delta, facilitated early

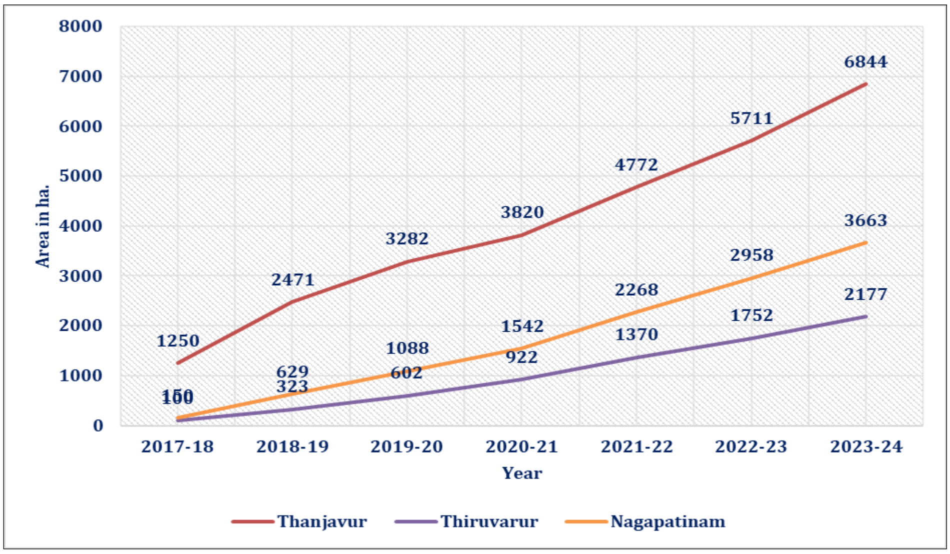

Fig. 4. Trends in maize cultivation area in the Cauvery delta sub-basin.

adoption and sustained growth in maize cultivation. Farmers in this region rapidly adopted maize due to its significantly lower water requirement–about 80 % less than paddy–and its high profitability.

In Thiruvarur, the area under maize cultivation expanded significantly from 100 ha in 2017-18 to 3663 ha in 2023-24. This rapid expansion indicates a transformative shift in cropping patterns within a district where maize cultivation was initially minimal. The success of maize in Thiruvarur can be attributed to the awareness created about its adaptability to local soil conditions and suitability as a water-efficient crop. The adoption highlights the district's successful efforts to diversify crops and mitigate the risks of water scarcity.

Nagapattinam experienced the most dramatic growth, with maize cultivation increasing from 150 ha in 2017-18 to 2177 ha in 2023-24. Being at the tail-end of the delta, Nagapattinam has traditionally faced significant water challenges. The sharp rise in maize cultivation reflects the impact of improved water management practices, project-driven capacity-building initiatives and farmers' willingness to adopt resilient cropping systems. The significant growth in this region underscores the project’s effectiveness in addressing water-related constraints.

Overall, maize cultivation in the Cauvery Delta sub-basin expanded from 1500 ha in 2017-18 to 12684 ha in 2023-24, a substantial 845.6 % increase. This remarkable growth demonstrates the success of targeted interventions in promoting maize as a resilient, water-efficient crop. The adoption of maize, particularly in middle and tail-end districts like Thiruvarur and Nagapattinam, underscores the role of collaborative efforts in achieving crop diversification and improving farmers' resilience to water scarcity. The findings highlight the transformative impact of the TNIAMP, emphasizing its contribution to enhancing agricultural sustainability in the Cauvery Delta sub-basin. It is expected that farmers in the delta regions who initially refrained from cultivating maize may adopt it in the subsequent year, as maize requires less water than rice and offers higher income.

Conclusion

The Cauvery Delta, once the "Granary of Peninsular India," faces increasing water scarcity and climate challenges. The TNIAMP has promoted maize as a viable alternative to paddy due to its higher economic returns (BC ratios of 1.77 for fresh cob and 2.68 for dry seed, compared to 1.06 for paddy) and greater water-use efficiency. Over time, cropping patterns have shifted, with the HI rising from 0.35 (2007-08) to 0.51 (2023-24) and the EI declining index value from 1.00 to 0.84, indicating reduced crop diversity and the dominance of maize. In Thanjavur, Thiruvarur and Nagapattinam, maize cultivation has surged, with area increasing by 889.64 % and production by 2695.96 % over 74 years, while paddy area has declined by 19.36 % in two decades.

To sustain this transition, policies should promote maize in water-scarce regions, particularly during the kuruvai season, while mitigating salinity and irrigation challenges. Encouraging crop diversification beyond maize and enhancing farmer training on resource-efficient technologies will strengthen agricultural resilience. These measures will foster sustainable development, improve farmer livelihoods and ensure long-term agricultural viability in the delta.

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Authors' contributions

SK designed the research framework, coordinated the field activities, contributed to manuscript writing and supervised the overall study. VM performed critical revisions and finalized the manuscript. GD handled data analysis and contributed to drafting sections of the manuscript. CS assisted in field data collection, literature review and initial data compilation. SP provided technical inputs on agronomic aspects and reviewed the final draft. All authors read and approved the final manuscript.

Compliance with ethical standards

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During the preparation of this work, the authors used OpenAI for language editing and refining the structure of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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