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Impact of Climate Change Assessments on Horticultural Crop Dynamics in Tamil Nadu, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study aims to analyze the dynamics of horticultural crop production in Tamil Nadu amidst climate change, focusing on trends, challenges, and opportunities across diverse agro-climatic zones, primarily considering variations in rainfall.
Data: The research utilizes comprehensive datasets spanning a decade (2012-13 to 2021-22) encompassing records of rainfall, horticulture cultivation area, and production. The study focuses on major horticultural crop categories, including fruits, vegetables, plantation crops, spices and condiments, medicinal and aromatic crops, and flowers.
Objective: (1) analyze compound annual growth rates of area, production, and productivity of key horticultural crops in Tamil Nadu, (2) conduct decomposition analysis over a decade for horticultural crops, and (3) assess climate change impact on agricultural production in Tamil Nadu focusing on rainfall patterns.
Methodology: The study utilizes various analytical tools, including Compound Annual Growth Rate (CAGR) analysis, percentage analysis, decomposition analysis, and the Cobb-Douglas production function. Secondary data from government publications, including the Season and Crop Report of

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Tamil Nadu and the Department of Horticultural and Plantation Crop Report of Tamil Nadu, are utilized for analysis.

Results: The analysis reveals intricate patterns influenced by climate variability, with certain zones demonstrating harmonious growth, while others contend with challenges related to cultivation and productivity. The decomposition analysis highlights the respective contributions of changes in cultivation area and crop yield to variations in production, underscoring the impact of climate change on agricultural dynamics. Additionally, the Cobb-Douglas production function analysis indicates significant effects of both rainfall and cultivation area on horticultural production, emphasizing the multifaceted nature of factors influencing production trends.

Keywords: Agro-climatic zones; climate change; Cobb-Douglas production function; compound annual growth rate; decomposition analysis.

1. INTRODUCTION

Globally, diverse climates and soils create abundant opportunities for growing a wide variety of horticultural crops, which play a significant role in total agricultural production. However, climate change, especially fluctuations in rainfall patterns and unpredictable high temperatures, significantly affect horticultural production and productivity [1]. India, characterized by its diverse climate, encompasses various agro-ecological regions with distinct characteristics. This diversity offers numerous opportunities for cultivating a wide range of horticultural crops [2]. This study examines the dynamics of horticultural crops in Tamil Nadu within the context of climate change, focusing on trends, challenges, and opportunities across diverse agro-climatic zones considering mainly rainfall variations. Through compound annual growth rate (CAGR) analysis and decomposition analysis spanning a decade (2012-13 to 2021-22), the research evaluates the performance of major horticultural crop categories, including fruits, vegetables, plantation crops, spices and condiments, medicinal and aromatic crops, and flowers. The findings unveil intricate patterns influenced by climate variability, with certain zones demonstrating harmonious growth, while others contend with challenges related to cultivation and productivity. The analysis emphasizes the need for tailored, region-specific strategies to optimize horticultural crop production amidst changing climatic conditions and ensure sustainable agricultural development.

The Fourth Five Year Plan (1969-74) marked a crucial juncture by recognizing the significance of the horticultural sector in bolstering agricultural production, enhancing value addition, increasing farm incomes, and fostering employment opportunities [3]. India, with its robust agricultural economy, particularly in horticulture, serves as a cornerstone for economic growth and employment for around 70 percent of its rural populace [4]. As the country transitions from traditional to modern agriculture as part of broader modernization trends, horticulture has emerged as a key component of the cropping pattern, with high-value crops assuming greater significance [5]. Evolving dietary preferences and a burgeoning population have flood a surge in demand for nutritional requirements, presenting significant opportunities for agro-based industries [6]. India's status as the second-largest producer of fruits and vegetables worldwide positions it to leverage the growing demand in global markets, including nations such as Saudi Arabia, UAE, Nepal, Bhutan, Sri Lanka, and Bangladesh [7].

In the year 2020-21, Punjab was the leading state in horticultural productivity, achieving a yield of 19.16 t/ha, with West Bengal and Bihar following closely at 17.94 t/ha and 17.32 t/ha, respectively. Tamil Nadu, on the other hand, ranked 8th nationally, contributing 12.77 t/ha to India's overall horticulture productivity [8]. Horticulture, recognized as a subset of agriculture, encompasses the cultivation of garden crops for food, medicinal purposes, or aesthetic satisfaction [9]. India's diverse agro-climatic zones provide ample opportunities for cultivating a wide variety of horticultural crops, including fruits, vegetables, flowers, spices, plantation crops, root and tuber crops, medicinal, and aromatic crops. However, the trends and growth of horticultural crops in the northwestern zone of Tamil Nadu serve as a focal point for this analysis, given the specific impacts of climate change. Understanding the challenges and opportunities in this region can offer valuable insights into optimizing cultivation practices, mitigating potential risks, and harnessing the full potential of the horticultural sector for sustainable development amid changing climatic conditions across Tamil Nadu. With the following objectives,

a. Examine the compound annual growth rates of the area, production, and productivity of key horticultural crops in Tamil Nadu,

b. Conduct a decomposition analysis for a decade-long period of horticultural crops in Tamil Nadu

c. Review the impact of climate change on agricultural production in Tamil Nadu by considering the Rainfall pattern.

d. To explore the intricacies of production trends along with climatic conditions.

2. MATERIALS AND METHODS

This study focuses on Tamil Nadu, comprising 38 districts across seven agro-climatic zones. North Eastern Zone (NEZ) districts include Chennai, Kancheepuram, Chengalpattu, Tiruvallur, Tiruvannamalai, Vellore, Ranipet, Tirupattur, Villupuram, Kallakuruchi, and Cuddalore. North Western Zone (NWZ) districts consist of Dharmapuri, Krishnagiri, Namakkal, and Salem. Western Zone (WZ) districts encompass Ariyalur, Coimbatore, Dindigul, Erode, Karur, Perambalur, Theni, and Tiruppur. Cauvery Delta Zone (CDZ) districts include Thanjavur, Mayiladuthurai, Thiruvarur, Trichy, and Nagapattinam. Southern Zone (SZ) districts consist of Pudukottai, Ramnadapuram, Sivagangai, Thirunelveli, Virudhunagar, Thenkasi, Madurai, and Thoothukudi. The High Rainfall Zone (HRZ) comprises Kanniyakumari, while the Hilly Zone (HZ) includes the Nilgiris. The selected major horticultural crop categories are fruits, vegetables, plantation crops, spices and condiments, medicinal and aromatic, and flower crops. This study utilizes secondary data from Government of Tamil Nadu publications, covering the area under major horticultural crops from 2012-13 to 2021-22 [10].

2.1 Compound Annual Growth Rate (CAGR)

For this investigation, secondary data encompassing the area, production, and productivity of horticultural crops spanning from 2012-13 to 2021-22 were gathered. The widely accepted methodology of calculating the Compound Annual Growth Rate (CAGR) was chosen as the analytical approach for this study.

The exponential compound annual growth rate is estimated using linear functions on time series data on horticultural crops viz., area, production, and productivity. The semi-log exponential functional form was used to analyze the trend in growth rate. It is one of the appropriate applicable forms to estimate the growth rate. The following semi-log functional form was used to estimate the growth rate.

$$Yt = Yo\ (1 + r)t \quad (1)$$

Where,
Y_t = Area under the crop at time t (ha)
r = Compound growth rate of Y
Y_o = Initial year area under the crop (ha)

By taking natural logarithm of (1),

$$In\ Yt\ =\ In\ Yo\ +\ t\ In\ (1 + r) \quad (2)$$

Now letting,
$\beta_1 = In\ Y_o$
$\beta_2 = In\ (1+r)$

Equation (2) can be written as

$$In\ \ Yt\ =\ \beta 1\ +\ \beta 2t \quad (3)$$

Adding the disturbance term to (3), it can be written as

$$In\ \ Yt\ =\ \beta 1\ +\ \beta 2t\ +\ Ui$$

Where,
Y_t = Area under crop at time 't' (ha)
t = time in years
β_1 = constant term
β_2 = regression co-efficient

This log linear function was fitted by using Ordinary Least Squares (OLS) method. The compound growth rate (r) was obtained using the formula [11].

$$\boldsymbol{r = (Antilog\ \text{of}\ \beta 2\ -\ 1) \times 100}$$

2.2 Percentage Analysis

Percentage analysis was utilized to compare the decadal differences in cultivation area and production of horticultural crops across various agro-climatic zones in Tamil Nadu. This method enabled a concise examination of proportional changes in crop cultivation and production over the specified period, facilitating the identification of significant trends and variations across zones.

2.3 Decomposition Analysis

Decomposition serves as a method for isolating the impact of factors such as technology advancement or environmental changes on production outcomes. The decomposition model, as outlined [12], aimed to estimate the respective contributions of changes in cultivation area and crop yield to variations in production, whether positive or negative in nature.

Change in production = Area Effects + Yield Effects + Interaction Effects

$$\mathbf{P = A0\,\Delta Y\,x\,100 / \Delta P + Y0\,\Delta A\,x\,100 / \Delta P + \Delta Y\,\Delta A\,x\,100 / \Delta P}$$

Where,
A_0 = Area in the base year
ΔA = Current area – Base area
Y_0 = Yield in the base year
ΔY = Current yield – Base yield
ΔP = Current production – Base production

2.4 Cobb-Douglas Production Function

This research investigates the production of horticultural crops in Tamil Nadu by using the Cobb-Douglas production function to establish a relationship between production (dependent variable), rainfall, and cultivated area (independent variables). It employs a decade-long dataset of rainfall, cultivation area, and production to quantify the impact of changes in these variables on horticulture production. By estimating coefficients for rainfall and area, the study aims to understand the percentage change in production resulting from a one percent change in each independent variable. The findings offer insights into the respective roles of rainfall and cultivation area in horticulture production, aiding decision-making in agriculture in the region [13].

3. RESULTS AND DISCUSSION

3.1 Variations in Area of Cultivation of Horticultural Crops

Table 1 presents the dynamics of horticultural crop cultivation across diverse zones, highlighting their response to climate change. The NEZ exhibits the highest annual growth rate in fruits crop area, indicating resilience to changing climatic conditions. NEZ and NWZ lead in fruit production, suggesting shifts in crops, yields, varietals, geographic move of production, etc. Water requirements and growing demand are outstanding issues in adaptation strategies to mitigate climate risks. The SZ demonstrates efficient productivity across crop types, reflecting climate-resilient farming practices. However, challenges persist, with the CDZ and HZ grappling with varying productivity levels. Climate variability, soil quality, and water availability play pivotal roles in shaping these dynamics, emphasizing the need for climate-smart agricultural strategies. NEZ's success could stem from favourable climatic conditions and advanced farming techniques, underscoring the importance of climate adaptation measures. Investments in sustainable irrigation practices are vital to mitigate water scarcity issues, particularly in regions like NWZ. Overall, these findings underscore the urgency of climate-conscious agricultural policies to ensure food security amidst changing climatic conditions [14].

3.2 Variations in Production of Horticultural Crops

Table 2 provides insights into the evolving dynamics of horticultural crop production in Tamil Nadu's diverse agro-climatic zones, emphasizing their responses to climate change. In the NEZ, there's a notable surge in fruits, vegetables, and flower production, reflecting efforts towards diversification and intensified cultivation practices resilient to climate variability. The NWZ has shown significant growth in flower cultivation alongside modest gains in fruits production, despite challenges in plantation crops. Conversely, the WZ witnessed a decline in fruit and flower production but a substantial rise in plantation crops, suggesting adaptation strategies to be developed specific to that zone. This may include encouraging varieties of flower cultivation, modern methods of flower cultivation, export incentives, pest and use of disease resistance high yielding varieties. Due to climate changes cropping patterns may result in changing sowing dates of crops or shift in seasons, as well as establishing and rearranging orchards or new variety of crop development. The CDZ face declines in various crop categories, highlighting vulnerabilities to changing climatic conditions. In the SZ, there's remarkable growth across fruits, vegetables, and spices and condiments production, indicating adaptive agricultural practices amid shifting climatic patterns. Meanwhile, the HRZ and HZ maintain relatively stable production patterns, underscoring the importance of resilience-building measures. The major factor affecting the production patterns are due to unseasonal

Table 1. CAGR (%) for area, production and productivity of horticultural crop categories in agro-climatic zones in Tamil Nadu (2012-13 to 2021-22)

CROPS	FRUITS			VEGETABLES			SPICES & CONDIMENTS			PLANTATAION CROPS			MEDICINAL & AROMATIC PLANTS			FLOWERS		
	Area	Pro	Pdy	Area	Pro	Pdy	Area	Pro	Pdy	Area	Pro	Pdy	Area	Pro	Pdy	Area	Pro	Pdy
NEZ	3.76***	2.82	-0.90	11.11***	9.96**	-1.03	5.37**	5.73*	0.35	-0.78	9.74***	10.61***	12.89	10.77	-1.88	7.87***	8.62***	0.69
NWZ	2.02	1.04	-0.96	8.02***	9.99***	1.83*	-1.42	3.85	5.35***	3.45	8.13**	4.52	3.65	3.51	-0.14	17.35***	16.10***	-1.06
WZ	0.49	0.47	-0.02	6.15***	5.72***	-0.41	-2.87**	-2.05	0.84	1.36	5.28	3.87	5.22	-2.18	-7.04	-0.56	-3.45*	-2.89*
CDZ	-1.43**	-4.95**	-3.58	5.86***	3.58*	-2.15	-3.23*	7.83	11.43***	1.22***	2.89	1.65	-13.38***	-15.55*	-2.50	1.75**	1.10	-0.64
SZ	3.28	0.53	-2.67	11.47***	6.74	-4.24*	0.07	2.74	2.67	0.14	5.06***	4.91**	-4.90*	-11.47*	-6.91	-0.19	-1.83**	-1.64
HRZ	-2.40*	-2.41	9.45	2.31	2.57	0.24	1.07***	8.50*	7.34	0.13	-3.14	-3.50	7.99	4.06	-3.64	-8.83***	-11.75**	-3.20
HZ	0.29	-1.23	8.52	1.90	-0.31	-2.33	2.25*	13.04*	10.54	-0.17*	-2.99*	-2.83*	-10.12*	-4.05	6.75	-9.79**	10.93	19.18**

(Note: ***, ** and *, indicates 1 per cent, 5 per cent and 10 per cent level of significance, Pro: Production, Pdy: Productivity).

Table 2. Zone-wise percentage share of production under horticultural crops in Tamil Nadu between 2012-13 and 2021-22

Crops	Fruits		Vegetables		Flowers		Spices and Condiments		Plantation crops		Medicinal and Aromatic plants	
	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22
NEZ	17.73	21.87	15.42	18.82	20.42	20.00	8.97	9.82	3.56	8.24	35.32	49.78
NWZ	10.44	11.76	43.11	41.65	25.49	54.95	32.41	38.06	10.29	11.25	28.03	30.00
WZ	39.40	34.68	25.52	24.63	29.59	12.33	42.14	29.12	43.45	38.17	13.52	6.39
CDZ	10.89	7.23	6.51	3.77	4.94	3.31	4.01	5.11	8.91	12.29	3.75	1.05
SZ	18.16	21.70	5.28	8.31	18.26	9.05	10.29	12.10	11.56	14.47	19.29	12.54
HRZ	2.83	2.22	0.72	0.62	0.82	0.18	0.95	2.53	7.03	4.81	0.04	0.19
HZ	0.55	0.54	3.46	2.20	0.49	0.18	1.23	3.27	15.19	10.78	0.05	0.05
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

rainfalls or heavy downpours in short duration resulting in unmanageable water conservation. This requires deepening and strengthening of irrigation channels, lakes, tanks, recharging of ground water sources and adoption of micro irrigation and nano-technologies. These shifts underscore the imperative for climate-resilient agricultural strategies to ensure sustainable horticultural production across Tamil Nadu's diverse agro-climatic zones [14].

3.3 Percentage Variation of Area under Horticultural Crops between the Zones

Table 3 demonstrates notable shifts in crop cultivation patterns across Tamil Nadu's agro-climatic zones over the decade (2012-13 to 2021-22), signalling responses to climate change. In the NEZ, there's substantial expansion in fruits, vegetables, and flower cultivation, indicative of adaptation and diversification strategies amidst changing climatic conditions. The NWZ sees an uptick in flower cultivation alongside a slight decline in plantation crops, reflecting adjustments to climate variability. Conversely, the WZ witnesses a decline in vegetable cultivation but a rise in plantation crops, suggesting adaptive shifts in response to climate impacts. In the CDZ, a decrease in area under medicinal and aromatic plants is observed, possibly influenced by changing climate patterns. The SZ experiences significant growth in spices and condiments, likely driven by climate-induced agricultural adjustments. Meanwhile, the HRZ and HZ maintain relatively stable cultivation patterns, highlighting resilience amidst climate uncertainties. These changes underscore the importance of climate-resilient agricultural strategies tailored to each agro-climatic zone. To encourage the farmers to adopt micro irrigation along with mulching practices, small farmers in particular may be encouraged to shift to micro cultivation practices like bonsai making, kitchen gardening at home and diversifying into less water intensive varieties. Farmers with small holdings could focus on cultivating different vegetable crops in small areas so as to cushion themselves against price fluctuations and to ensure sustainable horticultural production in Tamil Nadu [15].

3.4 Percentage Variation of Area under Horticultural Crops among the Zones

Table 4 presents an insightful overview of crop cultivation dynamics across diverse zones in Tamil Nadu, shedding light on the evolving landscape amidst climate change. The analysis unveils consistent upticks in vegetable cultivation areas across all zones, while other crop categories exhibit mixed trends over the decade. Specifically, the NEZ and NWZ experience expansions in vegetable and flower cultivation areas, alongside contractions in fruits, spices and condiments, plantation crops, and medicinal and aromatic crops. Similarly, the WZ witnesses growth in vegetables cultivation areas amidst declines in other crops. In CDZ, there are rises in vegetable and medicinal and aromatic crop cultivation areas, counterbalanced by reductions in other crop categories. The SZ sees increases in vegetable cultivation areas but decreases in other crops. Furthermore, the HRZ and HZ exhibit increments in vegetable and plantation crop cultivation areas, with reductions in other crop categories. Throughout the past decade, Tamil Nadu has experienced diminished cultivation areas for fruits, flowers, spices, plantation, and medicinal crops, contrasted with the ascending trend in vegetable cultivation. These shifts are likely influenced by changing climatic conditions, which impact crop suitability and productivity, alongside evolving market dynamics and governmental initiatives to incentivize vegetable farming. This analysis underscores the resilience and adaptability of vegetable cultivation in the face of climate change, highlighting its enduring profitability and demand across all zones, while also indicating the variable trends observed in other crop categories [2].

The following charts depict the trends in area of different crops and categories and respective production of crops.

3.5 Decomposition Analysis for Horticultural Crops

Table 5 provides an in-depth exploration of the decomposition analysis conducted over a decade, offering nuanced insights into the production trends of various horticultural crops across different zones in Tamil Nadu amid the backdrop of climate change. In fruit crop cultivation, zones like the NEZ and NWZ demonstrate cohesive growth, characterized by increases in both cultivated area and productivity, resulting in robust production. Conversely, zones like the WZ and HRZ present intricate dynamics, showcasing productivity gains despite reductions in cultivated land. Similarly, the analysis of vegetable crops reveals divergent scenarios, with NEZ encountering challenges in both area and

Table 3. Percentage share of Area under horticultural crops between the zones in Tamil Nadu between 2012-13 and 2021-22

Crops	Fruits		Vegetables		Flowers		Spices and Condiments		Plantation crops		Medicinal and Aromatic plants	
	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22
NEZ	17.83	21.89	14.46	19.50	22.56	23.12	6.70	9.97	11.01	9.16	5.00	5.67
NWZ	21.95	22.11	40.44	37.17	25.17	48.09	23.18	21.88	9.92	9.75	3.88	3.00
WZ	30.44	29.05	28.65	24.79	26.48	14.11	25.01	21.25	44.91	47.91	7.59	8.77
CDZ	7.29	5.75	5.59	4.79	5.41	3.79	3.60	2.41	0.11	0.03	78.10	79.72
SZ	19.31	18.68	7.16	11.14	19.30	10.55	37.99	40.11	14.69	14.46	5.41	2.80
HRZ	2.89	2.15	0.61	0.48	0.70	0.24	1.46	1.84	8.98	8.68	0.01	0.04
HZ	0.31	0.37	3.10	2.13	0.38	0.10	2.06	2.53	10.39	10.00	0.02	0.01
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 4. Percentage share of area under horticultural crops among the zones in Tamil Nadu between 2012-13 and 2021-22

Crops	Fruits		Vegetables		Flowers		Spices and Condiments		Plantation crops		Medicinal and Aromatic plants		Total
	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	2012-13	2021-22	
NEZ	32.16	30.75	15.69	32.55	3.54	4.55	5.25	5.02	41.21	25.17	2.15	1.96	**100.00**
NWZ	27.43	21.97	30.39	43.88	2.73	6.69	12.57	7.79	25.72	18.95	1.16	0.73	**100.00**
WZ	19.53	17.72	11.06	17.96	1.48	1.20	6.96	4.64	59.81	57.16	1.16	1.31	**100.00**
CDZ	23.12	17.71	10.67	17.51	1.49	1.64	4.95	2.66	0.73	0.19	59.03	60.29	**100.00**
SZ	26.24	24.34	5.85	17.25	2.28	1.92	22.41	18.73	41.46	36.86	1.75	0.90	**100.00**
HRZ	12.79	10.52	1.62	2.79	0.27	0.16	2.80	3.23	82.51	83.25	0.01	0.05	**100.00**
HZ	1.24	1.57	7.57	10.81	0.13	0.06	3.63	3.88	87.41	83.67	0.02	0.01	**100.00**
Tamil Nadu	22.54	20.46	13.56	24.31	1.96	2.86	9.78	7.33	46.79	40.02	5.37	5.02	**100.00**

Table 5. Decomposition analysis for Horticultural crop categories in agro-climatic zones in Tamil Nadu (2012-13 to 2021-22)

CROPS	FRUITS			VEGETABLES			SPICES & CONDIMENTS			PLANTATAION CROPS			MEDICINAL & AROMATIC PLANTS			FLOWERS		
	AE	YE	IE	AE	YE	IE	AE	YE	IE	AE	YE	IE	AE	YE	IE	AE	YE	IE
NEZ	17.34	76.94	5.72	-6.37	118.40	-12.02	10.78	85.66	3.56	127.89	-8.68	-19.21	-73.86	193.55	-19.69	9.80	82.48	7.72
NWZ	64.04	30.09	5.86	4.10	91.94	3.96	156.44	-32.05	-24.38	98.08	1.49	0.42	-1.66	101.43	0.23	8.81	70.63	20.56
WZ	-72.36	174.84	-2.48	10.21	81.09	8.70	-120.04	191.25	28.79	-140.48	253.04	-12.57	113.93	-47.13	33.20	62.29	42.14	-4.42
CDZ	43.59	62.72	-6.31	-142.67	361.42	-118.76	274.97	-65.11	-109.86	68.05	22.41	9.54	26.28	92.53	-18.81	28.30	65.42	6.28
SZ	83.41	12.57	4.02	0.14	99.52	0.34	118.01	-11.43	-6.58	98.46	1.05	0.49	19.50	88.72	-8.22	-327.69	412.24	15.45
HRZ	-145.07	217.27	28.26	8.84	85.05	6.14	83.98	5.42	10.73	94.94	6.21	-1.14	-8.53	144.22	-35.64	43.87	74.38	-18.23
HZ	-73.20	195.13	-21.93	-22.01	132.23	-10.26	87.05	4.17	8.58	91.28	10.21	-1.52	-180.85	210.64	70.21	-219.35	204.93	114.55

(Note: AE: Area Effect, YE: Yield Effect and IE: Interaction Effect)

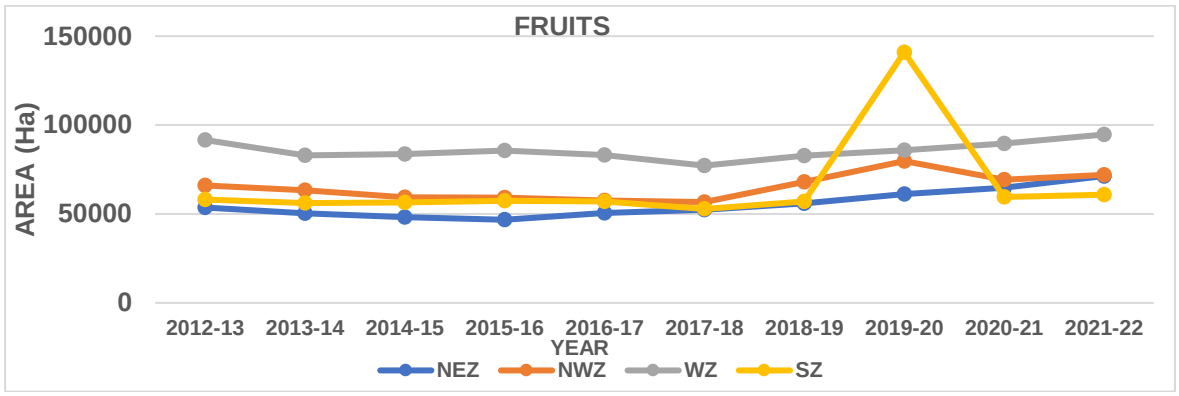

Fig. 1. Decadal trend of Area under Fruits (2012-13 to 2021-22)

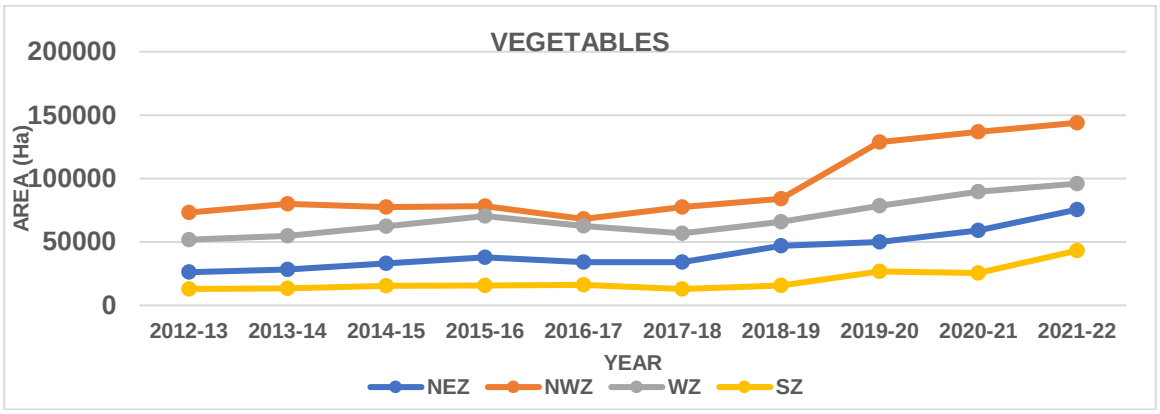

Fig. 2. Decadal trend of Area under Vegetables (2012-13 to 2021-22)

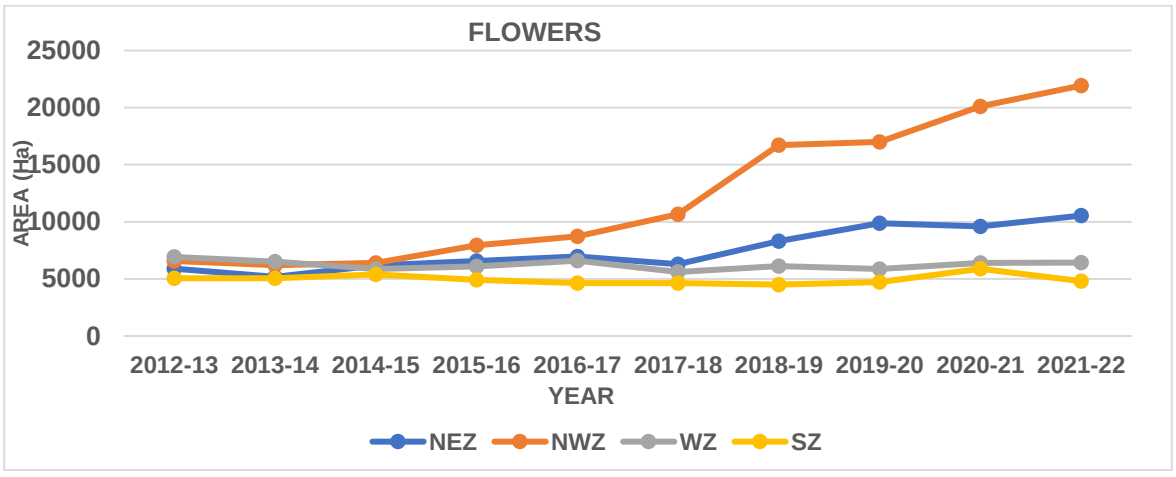

Fig 3. Decadal trend of Area under Flowers (2012-13 to 2021-22)

yield, while zones such as NWZ and WZ exhibit positive trends in both aspects. The analysis of spices and condiments crops underscores the intricate nature of production dynamics, with varying trends observed in NWZ and CDZ. In plantation crops, NEZ experiences an expansion in cultivated land alongside declining productivity, while WZ witnesses a reduction in area but significant productivity gains. Examination of medicinal and aromatic crops unveils complex patterns, including productivity enhancements offsetting declines in cultivated land in NWZ and HRZ, while the HZ sees notable productivity increases despite a decrease in cultivation area.

Finally, the analysis of flower crops highlights diverse trends across zones, with significant productivity gains observed in HZ and SZ despite reductions in cultivated land, while WZ demonstrates area expansion but faces yield challenges. These findings underscore the imperative of tailored strategies to address the unique challenges and capitalize on the opportunities presented by climate change in each zone, thus optimizing crop production effectively.

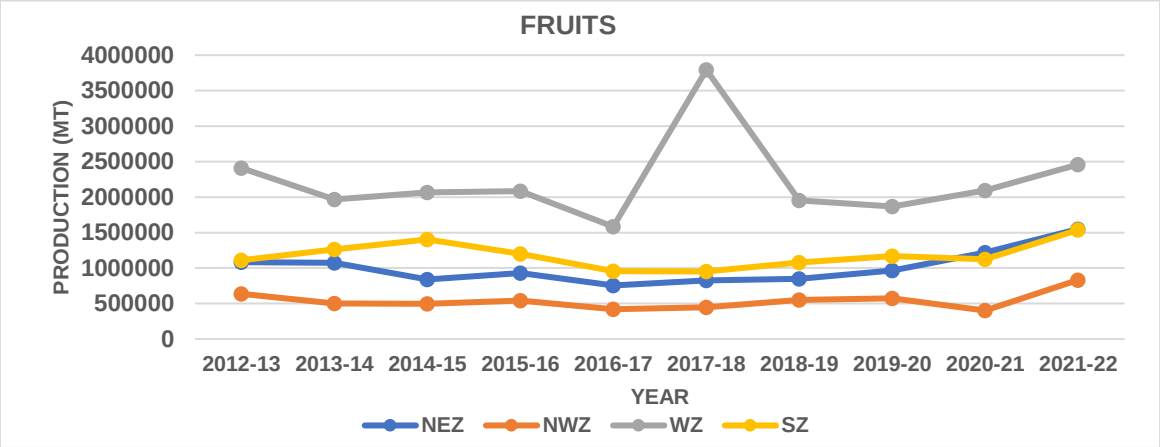

Fig. 4. Decadal trend of Production under Fruits (2012-13 to 2021-22)

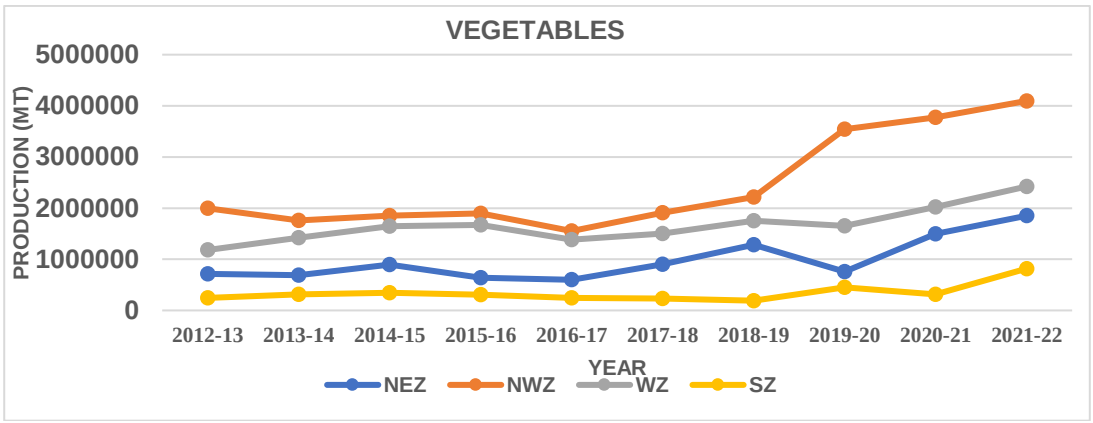

Fig. 5. Decadal trend of Production under Vegetables (2012-13 to 2021-22)

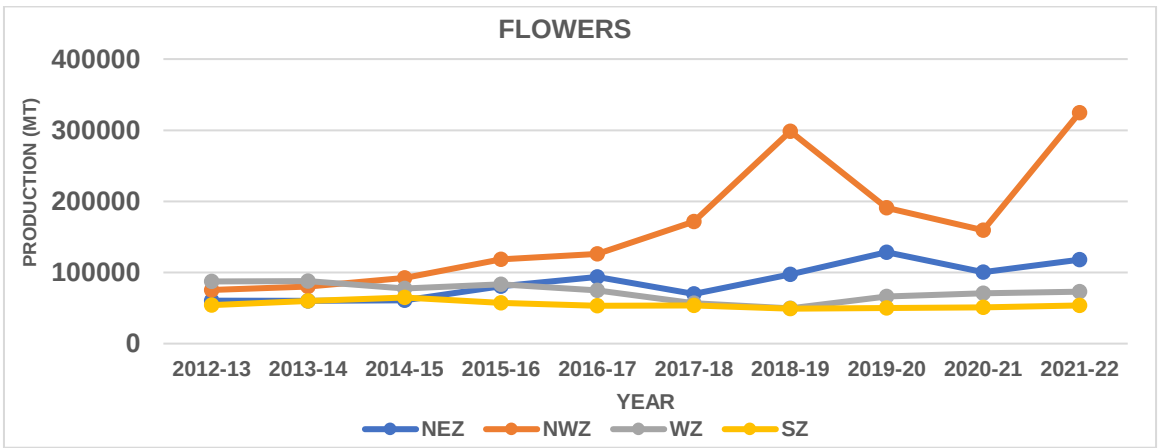

Fig. 6. Decadal trend of Production under Flowers (2012-13 to 2021-22)

Table 6. Analysis based on Decomposition analysis

Zone	Fruits	Vegetables	Flowers
NEZ	Yield effect 77 per cent	Yield effect 118 per cent	Yield effect 82 per cent
NWZ	Area effect 64 per cent	Yield effect 92 per cent	Yield effect 71 per cent
WZ	Yield effect 175 per cent	Yield effect 81 per cent	Area effect 62 per cent
SZ	Area effect 83 per cent	Yield effect 100 per cent	Yield effect 412 per cent

Table 7. Estimation of Cobb-Douglas production function of Horticultural crops in Tamil Nadu

Variables	Co-efficient	T-Value
Rainfall (X1)	0.176*	1.892
Area (X2)	1.680	5.476
F-Value		42.882***

*(Note: ***, ** and *, indicates 1 per cent, 5 per cent and 10 per cent level of significance)*

The analysis of decomposition across various horticultural crop categories in different zones from 2012-13 to 2021-22 reveals intricate and diverse patterns, highlighting the impact of climate change on agricultural dynamics. In fruit crops, the NEZ and NWZ demonstrate harmonious growth in both area and productivity, possibly due to adaptive agricultural practices micro irrigation along with mulching practices, diversified crop cultivation suited to changing climatic conditions. Conversely, the WZ shows increased productivity despite a reduction in cultivated land, indicating the adoption of climate-resilient cultivation techniques. The CDZ faces nuanced challenges, likely exacerbated by climate variability, while the SZ experiences synergistic growth, possibly driven by favourable climatic conditions for certain crops. The HRZ showcases remarkable productivity gains despite a decrease in cultivation area, suggesting adaptation of strategies to climate-related constraints. Similarly, the HZ experiences challenges but demonstrates significant productivity increases, reflecting adaptive measures. In vegetable production, positive trends in zones like NWZ and HRZ may indicate successful climate adaptation strategies, whereas challenges in CDZ may stem from climate-related factors. The decline in both area and yield of spices and condiments crops in NWZ highlights the vulnerability of certain crops to climate change impacts. The vulnerability of horticultural crops to climate change impacts in NWZ can be attributed to several factors, including increased temperatures, erratic rainfall patterns, and extreme weather events. These conditions can disrupt the growth and development of crops, leading to reduced yields and productivity. Additionally, changes in pest and disease incidents, as well as shifts in the availability of pollinators, which can further exacerbate the vulnerability of these crops. Furthermore, climate change may also affect the quality and market value of these crops, as changing environmental conditions can impact their flavor, aroma, and nutritional content. The complex interactions between climate change and crop vulnerability underscore the importance of adaptive measures and resilient agricultural practices to mitigate the negative impacts and ensure the sustainability of horticultural production in the face of changing climatic conditions [16]. Contrasting with CDZ's expansion but declining productivity, possibly influenced by changing climatic conditions. Plantation crops in NEZ exhibit complex dynamics, likely influenced by climate variability, while WZ shows increased productivity despite reduced cultivation area, possibly due to climate-resilient agricultural practices. Productivity boosts in medicinal and aromatic crops in NWZ and HRZ amidst challenges suggest successful adaptation efforts. Flower crop dynamics reflect varying responses to climate change, with SZ and HZ demonstrating increased productivity despite reduced cultivation, possibly indicating adaptive agricultural practices. Overall, these findings emphasize the importance of climate-resilient strategies tailored to the specific challenges posed by climate change across diverse agro-climatic zones to optimize horticultural crop production sustainably.

This underscores the significance of the yield effect, particularly in vegetable cultivation across the zones, suggesting the adoption of high-yielding varieties and modern cultivation techniques amid the challenges posed by climate change.

Table 7 explains over the decade spanning from 2012-13 to 2021-22, Tamil Nadu's horticultural production and cropping areas that have likely experienced significant impacts from climate

change. The Cobb-Douglas production function analysis indicates that both rainfall and area have substantial effects on production, with rainfall showing a positive but relatively smaller coefficient compared to area. Climate change-induced alterations in rainfall patterns could have influenced production dynamics, potentially leading to shifts in cropping patterns, changes in water availability, and alterations in cultivation practices. It could be noticed that the average on rainfall reached 100 and 110 centimetres an average in 2014-15 and 2015-16 from 80 cm in 2013-14. In 2016-17, rainfall dipped to 60 cm and rose to 102 cm in the subsequent year. However 2021-22 witnessed the highest rainfall of 140 cm during the reference period. When compared with production, high rainfall years witnessed high production and lower rainfall witnessed lower production levels. Moreover, variations in temperature, humidity, and extreme weather events could have influenced crop yields and the suitability of certain horticultural crops for cultivation in specific regions of Tamil Nadu. The increasing significance of area in the production function suggests that factors beyond climate, such as technological advancements, policy interventions, and market dynamics, have also played pivotal roles in shaping horticultural production trends. However, the exact magnitude and direction of these impacts would require detailed empirical analysis and consideration of broader socio-economic factors [17].

4. CONCLUSION

The evaluation of agricultural performance in various zones highlights the intricate interplay of factors that influence the cultivation of horticultural crops in the context of climate change. Regions like the NEZ and NWZ stand out as leaders in fruit and vegetable production, showing synchronized growth in both cultivation area and productivity, which could indicate successful adaptation to changing climatic conditions. However, each zone faces unique challenges and opportunities. For instance, the HRZ and WZ have managed to increase productivity despite a reduction in cultivated land, suggesting resilience to climate-related constraints. This complexity also extends to the analysis of spices and condiments, plantations, medicinal and aromatics, and flower crops, where diverse trends and challenges necessitate customized strategies. The agricultural landscape in each zone is shaped by climate, soil quality, water availability, agricultural practices, and infrastructure development, underscoring the need for a comprehensive understanding and climate-resilient approaches to optimize horticultural crop production sustainably. In Tamil Nadu, climate change has likely had a significant impact on horticultural production and cropping areas. The Cobb-Douglas production function analysis has shown that both rainfall and the area of cultivation have had substantial effects on production. Rainfall has a positive but relatively smaller coefficient compared to the area of cultivation. Climate change-induced changes in rainfall patterns may have affected production dynamics, leading to shifts in cropping patterns, changes in water availability, and alterations in cultivation practices. Strategies like these are crucial for ensuring food security, economic growth, and environmental sustainability across diverse agro-climatic zones in the face of climate change.

5. SUGGESTIONS

To boost horticultural crop production amid climate change, tailored strategies should prioritize diversification, sustainable agricultural methods, enhanced infrastructure, farmer capacity-building programs, and supportive grassroots-level policies. There are opportunities to adjust crop patterns to favor fruits in NWZ and SZ, and to expand flower cultivation in WZ. Additionally, there's potential to shift crop cultivation towards fruits, vegetables, and flowers in NEZ and WZ, in line with resilient agricultural practices.

A more detailed examination at the district, taluk, or village level would offer further insights into the impact of climate change on small land holdings and small and marginal farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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