Original Research Article

Vanishing paddies: Tracing the transformation of rice cultivation in Kerala

ABSTRACT

The study of rice cultivation in Kerala from 1957-58 to 2022-23 reveals a significant decline in the area under cultivation, dropping from 7.66 lakh ha to 1.91 lakh ha, driven by factors such as land conversion for non-agricultural purposes, labour shortages, and a shift to more profitable crops like rubber and coconut. Despite a notable increase in productivity from 1,188 kg/ha to 3,108 kg/ha, thanks to technological advancements, these gains were insufficient to offset the decline in area, leading to an overall reduction in production. Government interventions, including the Kerala Conservation of Paddy Land and Wetland Act of 2008, slowed the decline, but the trend persisted. A district-wise analysis revealed notable regional disparities, with Ernakulam, Thrissur, and Palakkad experiencing the most significant declines in terms of the total area lost under rice cultivation. Period-wise, the most severe reduction occurred during Period 3 (1996-97 to 2006-07), while Period 4 (2007-08 to 2022-23) saw a more moderate decline due to policy efforts. Moving forward, policies need to focus on better land-use management, protection of paddy fields and wetlands, and economic incentives to sustain rice farming in Kerala.

Key words: *Rice area decline; Structural breaks; District-wise analysis; Agricultural land-use shifts; Yield improvement*

1. INTRODUCTION

Rice is the staple food for more than half of the global population [1] The global rice sector faces a challenge in meeting future rice demand due to the growing global population, which is expected to increase to 8.9 to 10.6 billion by 2050 [2]. With growing populations and changing climate conditions, rice production systems face significant challenges, including diminishing water resources, declining arable land, and increasing temperatures [3]. These global trends are forcing countries to rethink rice production strategies to ensure long-term food security.India, the world’s second-largest rice producer [1],grows rice on approximately 44 million ha[4]. The Green Revolution in the 1960s brought significant productivity improvements through the adoption of high-yielding varieties (HYVs), irrigation expansion, and enhanced agricultural inputs [5]. However, recent decades have seen stagnation in growth due to challenges such as land degradation, urban expansion, and resource competition. In particular, the rice sector faces pressures from rising input costs, climate variability, and shrinking arable land [6].

Kerala, a southern coastal state in India, has historically relied on rice cultivation as a central part of its agrarian economy. In the 1960s and 1970s, the state saw significant growth in the area under rice cultivation [7]. However, by 2022-23, the area had drastically reduced to 1.91 lakh ha from its peak[8, 9]. The state's rice production followed a similar trend, with a peak of 1.76 million tons to 0.59 million tons in 2022-23 [8, 9]. This decline is attributed to various socio-economic and environmental factors, including rapid urbanization, labour shortages, conversion of agricultural land to non-agricultural uses, and the shift to more profitable crops such as rubber and coconut [10]. Additionally, Kerala has faced challenges related to water scarcity and the impacts of climate variability, which have further stressed rice cultivation in rain-fed areas [11]. The significant decline in the area under rice cultivation in Kerala over the last six decades raises serious concerns about food security, rural livelihoods, and environmental sustainability.Over the years, rice cultivation in Kerala has gone through periods of both expansion and contraction, with significant fluctuations in area, production, and productivity. These trends reflect the complex interplay of agricultural, economic, and environmental factors that have shaped the trajectory of rice cultivation in the state. In certain periods, productivity gains have helped offset reductions in area under cultivation, while in others, a steep decline in both area and production has dominated. Identifying and understanding these turning points in rice cultivation is crucial for formulating effective policy interventions. Such insights can inform strategies aimed at reversing the decline, ensuring sustainable rice cultivation, and preserving the state's food security. Policy measures that are grounded in an understanding of these shifts can help target the root causes of decline and promote practices that stabilize or enhance rice production, thus securing the agricultural future of Kerala.

1.1. Objective:

The primary objective of this study is to examine the dynamics of rice cultivation in Kerala by identifying structural breaks in long-term trends, analyzing changes in area, production, and productivity over time, and conducting district-wise analyses to assess regional disparities.

2. METHODOLOGY

2.1. Location of study

The study focuses on Kerala, a state situated in the southwestern region of India, known for its distinctive agricultural landscape and diverse ecological zones. Kerala has long been recognized for its rice cultivation, which forms a fundamental part of its agricultural economy and cultural heritage. The state's varied topography, ranging from coastal lowlands to midland hills and highland areas, provides diverse agro-climatic conditions conducive to rice farming. However, in recent decades, Kerala has experienced a steady decline in rice cultivation.

2.2. Data coverage and study period

The study is based on secondary data. The empirical data utilized in this investigation was acquired from the Department of Economics and Statistics, Kerala, from 1957-58 to 2022-23. This dataset encompasses comprehensive information about the acreage dedicated to rice cultivation, the volume of rice production, and the associated productivity metrics across various temporal segments. For a more detailed analysis, data from 1987-88 to 2022-23 were examined at the district level.

2.3. Analytical tools

2.3.a. Structural Break Analysis

The structural break analysis identifies significant changes in time series data. This study used methods from Gujarati et al. (2009) employing the Chow test to detect breakpoints by comparing F-statistics from unrestricted and restricted residual sums of squares. To address limitations like the assumption of constant variance, the Bai and Perron (1998) method was also applied for more robust detection of structural changes.

A multiple linear regression model with m breakpoints (resulting in $m + 1$segments), where each segment is constrained by a minimum length$h$, can be represented as:

$$y_t = x_t'\beta + z_t'\delta_j + u_t t = T_{j-1} + 1, \dots \dots \dots, T_j - - - - - (1)$$

$For\ j = 1, \dots \dots ., m + 1$

Where:

y_t= dependent variable at time t

$x_t(p \times 1) and\ z_t(q \times 1) = vectors\ of\ covariates$

$\beta\ and\ \delta_j(j = 1,2, \dots \dots .., m + 1) = corresponding\ vectors\ of\ coefficients$

$u_t = disturbance\ at\ time\ t$

In this approach, the breakpoints (T_1, …, T_m) are treated as unknown, with T_0= 0 and T_{m+1}= Tassumed. The objective is to estimate both the regression coefficients and these breakpoints when Tobservations on (y_t, x_t, z_t) are available. This model is classified as a partial structural change model because the parameter vectorβ remains constant throughout the sample. However, when p=0,the model becomes a pure structural change model, meaning all coefficients are allowed to change.Additionally, the variance of $u_t$does not have to be constant across segments. Variance can change, but it must align with the breakpoints in the regression parameters, allowing for both parameter shifts and breaks in variance within the same model.

2.1.b. Compound Annual Growth Rate

Compound Annual Growth Rates (CAGRs) were calculated using an exponential growth function to assess historical trends and performance in rice cultivation across Kerala and its districts, focusing on area, production, and productivity.

$$Y_t = ab^t e^u$$

$Y_t = dependent\ variable\ for\ which\ the\ growth\ rate\ was\ determined$

$a = intercept\ term$

$b = Regression\ coefficint = (1 + r)\ and\ r\ is\ the\ compound\ growth\ rate$

$t = time\ trend\ (include\ years\ with\ values\ 1,2,3 \ldots, n)$

$u = Disturbance\ term$

The LOGEST function in Microsoft Excel was used to estimate CAGR values, offering a more precise approach than traditional methods. By applying the Ordinary Least Squares (OLS) method, LOGEST utilizes all data points rather than just the initial and final values, capturing historical growth trends more accurately.

2.1.c. Decomposition Analysis

Decomposition analysis was used to quantify the contributions of three main factors to changes in rice production: area variance, yield variance, and area-yield covariances, including their interactions. The decomposition method helped isolate the impact of these components on production variability, providing insights into the factors driving changes over time [14]. The detailed methodology for this analysis is presented below.

The decomposition method used in this study separates the overall change in rice production into the contributions of changes in area and yield. The total change in rice production between the two periods t and $t-1$can be expressed as,

$$\Delta P = A_o \Delta Y + Y_o \Delta A + \Delta A \Delta Y$$

ΔP = change in total production between time t and $t-1$

ΔA = change in area under rice cultivation between time t and $t-1$

ΔY = change in yield between time t and $t-1$

The analysis was performed for each of the time periods to examine how these factors impacted rice production in Kerala over time.

2.1.d. Cuddy-Della Valle Instability Index (CVDI)

The Cuddy-Della Valle Instability Index (CVDI) was used to measure the instability of the area, production, and productivity of rice cultivation over time. The CVDI quantifies the degree of fluctuations or variability within a dataset. A higher CVDI indicates greater instability, while a lower CVDI suggests more stability. This index was applied to all three variables to assess the stability or volatility of rice cultivation in Kerala during different phases.

$$Instability\ index, IIN = \left(\frac{\delta}{\mu} \times 100\right) \times (1 - \bar{R}^2)^{0.5}$$

Where,

$\bar{R}^2$ = Adjusted coefficient of determination

μ = Mean

σ = Standard deviation

When the estimated parameter in the regression equation was found to be insignificant, the coefficient of variation (CV) was used as the instability index.

3. RESULTS AND DISCUSSIONS

A structural break refers to a significant shift in the underlying trend or pattern within a time series dataset. There are four structural breaks identified in this study that represent the most critical phases in rice cultivation in Kerala.The breakpoints mark the division of the data into the following periods:1957-58 to 1986-87, 1986-87 to 1996-97, 1996-97 to 2006-07, 2007-08 to 2022-23

3.1. Trend in the rice cultivation

During the overall period from 1957-58 to 2022-23, the area under rice cultivation in Kerala drastically declined, reducing from 7.66 lakh ha to just 1.91 lakh ha by 2022-23, as depicted in Table 1. This represents a 75 per cent reduction in the cultivated area. The area even peaked at 8.81 lakh ha in 1974-75, further highlighting the dramatic 78.3 per cent decline compared to the peak. On the other hand, rice productivity saw continuous improvement throughout the period, rising from 1188 kg/ha in the earlier years to 3108 kg/ha by 2022-23. This consistent increase in productivity helped mitigate the adverse effects of shrinking cultivated areas. District-wise, the most significant declines in cultivation were observed in Ernakulam, Palakkad, and Thrissur. Ernakulam lost 75,189 ha, Palakkad reduced by 71,203 ha, and Thrissur saw a decline of 61,281 ha. Ernakulam experienced a significant reduction in production, losing 108,456 tons, a 90 per cent decline, while Thrissur saw a loss of 52,452 tons, as depicted in Table 3.Despite the decline in cultivated area, productivity gains were impressive. Malappuram's productivity increased by 2,103 kg/ha, Thrissur grew by 1,871 kg/ha, and Palakkad improved by 1,350 kg/ha. These improvements, driven by better farming practices, the introduction of high-yielding varieties (HYVs) and mechanization, helped offset some of the negative effects of the shrinking cultivation area [15]. The factors affecting rice cultivation in Kerala varied across different periods.

3.1.a. Period 1: 1957-58 to 1986-87

The first period, from 1957-58 to 1986-87, represents a crucial phase in Kerala's rice cultivation, marked by both expansion and initial signs of decline. During this time, the area under cultivation grew significantly, reaching a peak of 881,466 ha in the early 1970s before a gradual decline by the early1980s (Table 1). Despite the reduction in cultivated area towards the end of the period, productivity consistently improved, helping to maintain overall production levels. Rice production grew from 925,470 tons in 1957-58 to a peak of 1,761,590 tons in 1968-69.influenced by steady productivity gains, which rose from 1,188 kg/ha to 1,708 kg/ha by 1986-87.The yield effect was the main driver of production growth, contributing to 178.59 per cent of the overall increase in production (Table 7). This led to significant improvements in production, even when the area under rice cultivation declined. This trend was also evident in the compound annual growth rate (CAGR), where a negative growth rate of 0.18 per cent in the area was offset by a productivity increase of 1.12 per cent, resulting in overall production growth of 1.69 per cent, as shown in Table 2. The Cuddy-Della Valle Instability Index (CVDI)values indicated low instability across the variables of area, production, and productivity, suggesting that the gains in productivity were substantial enough to counterbalance the decline in area, maintaining relative stability in rice production.

A vital aspect of this period was The Kerala Land Reforms Act of 1963 and The Kerala Land Utilisation Order of 1967 were landmark legislations aimed at redistributing land, promoting equitable land use, and social change [16]. Additionally, this period coincided with the early waves of the Green Revolution, which introduced new agricultural technologies, high-yielding seed varieties, and improved irrigation techniques. The gradual introduction of modern farming methods and new varieties contributed to the steady rise in productivity between1957-58 to 1986-87.Despite the subsequent decrease in cultivated areas, these activities contributed to an initial growth in rice cultivation.The rapid expansion of coconut and rubber cultivation played a central role in the decline of rice cultivation in Kerala. Coconut cultivation grew significantly during this period, increasing from 4.6 lakh ha to 7 lakh ha, while rubber cultivation saw even more dramatic growth, expanding from 0.99 lakh ha to 3.4 lakh ha (Table 1). This transition offered higher economic returns and improved market demand. Farmers increasingly shifted their focus to these cash crops due to their profitability and favourable market conditions [17], which encouraged the conversion of rice fields into coconut and rubber plantations [7, 10].

3.1.b. Period 2: 1987-88 to 1996-97

The period from 1986-87 to 1996-97 marked a significant decline in rice cultivation in Kerala. The area under rice cultivation dropped sharply from 604,082 ha in 1987-88 to 430,826 ha in 1996-97, with a CAGR of -3.28per cent (Table 1 and 2). Although rice productivity continued to increase, reaching 2023 kg/ha with a growth rate of 1.56per cent, these gains were insufficient to compensate for the considerable reduction in cultivated area. This shift is reflected in the area effect, which showed a negative impact of 183.72 per cent, outweighing the positive yield effect of 117.39 per cent (Table 7). As a result, total rice production fell from 1,032,605 tons to 871,361 tons, showing a negative growth rate of 1.77per cent. There was also an increase in production instability during this time. The Instability Index for production rose to 6.80, indicating that the reduction in cultivated area made rice production more varied.

Most of the districts in Kerala saw a significant reduction in the area dedicated to rice cultivation. Thrissur experienced the most significant drop, losing 32,632 ha, a 38.8per cent decrease between 1987-88 and 1996-97 as reported in Table 3. While Alappuzha saw a sharp decline in production, losing 37,930 tons. Despite the losses in cultivated area and production, several districts recorded notable gains in productivity, with Wayanad experiencing an increase of 497 kg/ha. Palakkad and Wayanad showed positive growth in production, with growth rates of 0.45 per cent and 1.62 per cent, respectively (Table 5). In contrast, Thrissur and Ernakulam recorded negative growth rates in production. Nonetheless, all districts, except for Kottayam, demonstrated positive growth in productivity during this period as illustrated in Table 6.

This period was marked by a significant expansion of coconut and rubber cultivation, which became increasingly prominent. The area dedicated to these crops grew faster, reflecting a broader shift in Kerala's agricultural sector from food to non-food crops. By the end of this period, the area under coconut cultivation reached 9.1 lakh ha, while rubber cultivation expanded to 4.5 lakh ha (Table 1). This pointed out that the widespread conversion of paddy fields to cash crops is a significant factor in the decline of rice cultivation. The results are aligned with the findings reported by [7, 10, 18].

3.1.c. <u>Period 3: 1997-98 to 2006-07</u>

The third period, from 1996-97 to 2006-07, continued the decline in the area dedicated to rice cultivation in Kerala. The cultivated area dropped significantly from 387,712 ha to 263,529 ha, reflected in the steep negative growth rate of 4 per cent (Tables 1 and 2). This sharp decrease in rice area significantly impacted total rice production, which declined from 871,361 tons in 1996-97 to 641,575 tons in 2006-07. Rice productivity continued to rise, reaching 2435 kg/ha by the end of this period with a positive growth rate of 1.57 per cent, even though these productivity gains were not enough to compensate for the immense loss of cultivated area as reflected in the negative area effect of 198.42 per cent compared to the positive yield effect of 144.57 per cent (Table 7). This period also saw increased instability in rice production, with an instability index value of 5.58 per cent. The ongoing reduction in cultivated area, combined with the rising productivity, led to persistent instability in production. Overall, even though yield improved, the significant loss of rice area caused further reductions in total production and increased instability in Kerala's rice sector.

The trend of decline in the area under rice cultivation was also visible across the districts, with Ernakulam experienced the highest loss, with a decline of 30,227 ha, which was reflected in a negative growth rate of 3.65 per cent as depicted in Tables 3 and 4. This area reduction resulted in a significant decrease in production, with Ernakulam losing 30,227 tons, marking a negative growth rate of 8.35 per cent (Table 5). However, productivity continued to increase in all districts. Thiruvananthapuram saw a remarkable 52 per cent increase in productivity, with an increase of 893 kg/ha (Table 6). In terms of CAGR, all districts exhibited negative growth rates in area, with Kollam and Thiruvananthapuram recording the steepest declines. Regarding production, only the Palakkad district experienced positive growth. However, in terms of productivity, all districts showed positive growth rates except for Pathanamthitta, with Thiruvananthapuram achieving the highest growth rate of 3.63 per cent.

The area under coconut cultivation initially saw significant growth, peaking at 9.25 lakh ha during the early years. However, this was followed by a decline in the later period. In contrast, rubber cultivation continued to expand steadily, reaching 8.75 lakh ha by the end of the period (Table 1). However, the decrease in rice cultivation was more pronounced than in previous periods. This trend reflects the multifaceted impact of the shift toward other crops and the increasing demand for land driven by population growth. Kerala's population rose from 2.54 crore in 1990-91 to 2.9 crore, and by 2010-11, it reached 3.18 crore [19]. This population increase intensified the pressure on land for non-agricultural purposes. As the demand for housing and commercial development increased, rice fields were increasingly converted for non-agricultural purposes, further accelerating the decline in the area dedicated to rice cultivation [10]. This shift was driven by rising land prices relative to farming returns, which incentivized real estate ventures and contributed to the overall decline in paddy cultivation [20].

3.1.d. Period 4: 2007-08 to 2022-23

The final period, from 2007-08 to 2022-23, is notable for significant policy interventions addressing the decline in rice cultivation. The most significant policy intervention during this period was the Kerala Conservation of Paddy Land and Wetland Act of 2008, which aimed to protect the paddy and wetlands [21]. Its impact was evident in the growth rates of rice cultivation, with the compound annual growth rate (CAGR) of the area improved to -1.14 per cent (Table 2), compared to the earlier period. Along with this, productivity increased at a growth rate of 1.5 per cent, which ultimately led to a positive growth in production. Production rose from 528,488 tons in 2007-08 to 595,860 tons by 2022-23 as depicted in Table 1, with a modest growth rate of 0.34 per cent. The decomposition analysis made this clearer, with the yield effect contributing significantly at 271.73 per cent (Table 7). In contrast, the area and interaction effects had negative impacts, at 127.55 per cent and 44.18 per cent, respectively. Despite these negative influences, the positive yield effect outweighed them, leading to an overall increase in production, even as the area under rice cultivation declined. Considering the district-wise data in Alappuzha district, there was even an increase in the cultivated area, with Alappuzha recording a notable increase of 5,606 ha (Table 3) in its rice-growing land, indicating a reversal of earlier trends. However, other central rice-producing districts like Palakkad continued to experience a decline in rice cultivation. Several districts, including Pathanamthitta, Alappuzha, Kottayam, Thrissur, and Malappuram, exhibited positive growth in rice production as illustrated in Table 5. The continued reduction in the area under rice cultivation can be largely attributed to the growing pressure on land due to the increasing population, which surged to 3.34 crore by the 2017-18 census [19]. Around 58.9 per cent of agricultural households hold less than 0.4 ha of land, and 94.8 per cent of non-agricultural households fall into the same category [21], highlighting the rising demand for land. Additionally, while the area under coconut cultivation saw a slight decline, rubber cultivation fluctuated but ultimately increased by the end of the period. These factors combined further explain the reduction

Table 1. Area, production, productivity of crops from 1957-58 to 2022-23

Year	Rice			Coconut			Rubber		
	Area (ha)	Production (tons)	Productivity (kg/ha)	Area (ha)	Production (tons)	Productivity (nuts/ha)	Area (ha)	Production (tons)	Productivity (kg/ha)
1957-58	766773	925470	1188	463281	3199	6905	99875	21844	215
1961-62	752704	1003964	1334	504830	3247	6484	133079	24982	203
1966-67	799438	984062	1356	609593	3425	5619	151657	50795	329
1971-72	875157	1351730	1545	629576	3964	6296	188612	88929	471
1976-77	854374	1254003	1544	644985	3348	5191	209723	139349	664
1981-82	806871	1339393	1660	666618	2976	4509	237769	139455	587
1986-87	663803	1133786	1708	706107	3173	4494	347814	202129	581
1991-92	541327	1060350	1959	863061	4641	5377	425768	243109	571
1996-97	430826	871361	2023	902104	5276	5849	455566	512756	1126
2001-02	322368	703504	2182	905718	5479	6049	475039	580350	1222
2006-07	263529	641575	2435	872943	6054	6935	502240	780405	1554
2011-12	208160	568993	2733	820867	5941	7237	539565	798940	1481
2016-17	171398	436483	2547	781496	5384	6889	551050	540400	981
2022-23	191712	595860	3108	760354	5641	7419	551030	533500	968

Source: Department of Economics and Statistics, Government of Kerala

Table 2: Compound Annual Growth Rate (CAGR) and Cuddy-Della Valle Instability Index (CVDI) values of area, production and productivity

Time period	CAGR (%)			CVDI (%)		
	Area	Production	Productivity	Area	Production	Productivity
Period 1 (1957-58 to 1986-87)	-0.18	1.03	1.12	7.21	8.02	3.32
Period 2 (1987-88 to 1996-97)	-3.28	-1.76	1.56	2.79	6.81	3.99

Period 3 (1997-98 to 2006-07)	-4.00	-2.48	1.58	2.35	5.58	4.56
Period 4 (2007-08 to 2022-23)	-1.14	0.34	1.50	5.85	8.02	4.35
Overall period	-2.81	-1.49	1.39	16.41	17.96	6.32

Source: Estimated

Table 3:District wise area, production, and productivity under rice cultivation (1987-88 to 2022-23)

Year	Thiruvananthapuram	Kollam	Pathanamthitta	Alapuzha	Kottayam	Idukki	Ernakulam	Thrissur	Palakkad	Malapuram	Kozhikkode	Wayanad	Kannur	Kasargod
Area (ha)														
1987-88	23300	30227	14102	60763	29854	5368	79818	84176	144665	56471	15580	21299	22505	15954
1996-97	13961	22223	10985	41447	20200	5099	53988	51544	128359	31098	8316	17078	15421	11107
2006-07	3849	5497	2616	31060	13814	2878	21895	27311	109208	15109	4295	11832	8842	5323
2022-23	1720	1840	3618	38941	1840	364	4629	22895	73462	9618	1645	7700	3933	2307
Production (tons)														
1987-88	36577	53496	33490	123122	66062	10657	119810	130887	266049	79021	15996	36261	33606	27571
1996-97	24877	42237	23690	85192	43728	10578	93382	104966	294065	53443	10429	37563	26599	20612
2006-07	10077	12580	7101	90160	35550	7507	44007	65036	270103	33123	6092	30722	17375	12142
2022-23	4291	4368	11960	120213	58390	927	11354	78435	234249	33682	2290	21797	8715	5189
Productivity (kg/ha)														
1987-88	1570	1770	2375	2026	2213	1985	1501	1555	1839	1399	1027	1702	1493	1728
1996-97	1782	1901	2157	2055	2165	2075	1730	2036	2291	1719	1254	2199	1725	1856
2006-07	2618	2289	2714	2903	2573	2608	2010	2381	2473	2192	1418	2597	1965	2281
2022-23	2495	2374	3306	3087	3066	2547	2453	3426	3189	3502	1392	2831	2216	2249

Source: Department of Economics and Statistics, Government of Kerala

Table 4: District-wise Compound Annual Growth rate (CAGR) of area under rice cultivation

Time period	Thiruvananthapuram	Kollam	Pathanamthitta	Alapuzha	Kottayam	Idukki	Ernakulam	Thrissur	Palakkad	Malapuram	Kozhikkode	Wayanad	Kannur	Kasargod
Period 2 (1987-88 to 1996-97)	-4.62	-3.25	-3.24	-4.43	-3.31	-1.54	-3.55	-4.67	-1.07	-5.68	-6.92	-0.86	-3.68	-4.21
Period 3 (1997-98 to 2006-07)	-10.19	-12.66	-10.77	-3.24	-1.90	-3.62	-8.35	-3.88	-0.49	-6.89	-6.41	-5.07	-5.82	-5.17
Period 4 (2007-08 to 2022-23)	-3.45	-3.41	2.83	1.06	-2.14	-10.15	-6.20	-0.43	-1.92	0.12	-4.59	-3.66	-2.45	-5.00
Overall period	-8.44	-9.99	-5.33	-1.35	-2.16	-7.19	-9.56	-4.08	-2.26	-6.42	-5.93	-3.28	-4.78	-5.88

Source: Estimated

Table 5: District-wise Compound Annual Growth rate (CAGR) of rice production

Time period	Thiruvananthapuram	Kollam	Pathanamthitta	Alapuzha	Kottayam	Idukki	Ernakulam	Thrissur	Palakkad	Malapuram	Kozhikkode	Wayanad	Kannur	Kasargod
Period 2 (1987-88 to 1996-97)	-3.64	-2.20	-3.14	-3.47	-3.33	0.16	-2.49	-2.20	0.45	-3.49	-5.56	1.62	-3.07	-3.81
Period 3 (1997-98 to 2006-07)	-6.92	-10.45	-10.82	-2.55	-1.13	-2.09	-6.60	-1.58	0.10	-4.07	-4.52	-3.80	-3.92	-2.79
Period 4 (2007-08 to 2022-23)	-3.39	-3.75	4.40	2.06	3.32	-11.23	-4.99	1.71	-0.25	3.33	-4.92	-3.05	-1.74	-5.11
Overall period	-7.17	-9.44	-4.43	-0.23	-0.23	-7.00	-8.48	-1.85	-1.14	-4.10	-5.42	-2.29	-3.63	-5.05

Source: Estimated

Table 6: District-wise Compound Annual Growth rate (CAGR) of rice productivity

Time period	Thiruvananthapuram	Kollam	Pathanamthitta	Alapuzha	Kottayam	Idukki	Ernakulam	Thrissur	Palakkad	Malapuram	Kozhikkode	Wayanad	Kannur	Kasargod
Period 2 (1987-88 to 1996-97)	1.03	1.09	0.11	1.01	-0.03	1.72	1.10	2.58	1.53	2.33	1.46	2.50	0.65	0.43
Period 3 (1997-98 to 2006-07)	3.63	2.54	-0.07	0.72	0.79	1.58	1.91	2.39	0.59	3.03	2.01	1.33	2.01	2.51
Period 4 (2007-08 to 2022-23)	0.14	-0.12	1.54	1.33	0.36	-1.15	1.30	2.17	1.71	3.31	-0.05	0.64	0.89	-0.06
Overall period	1.41	0.70	0.96	1.24	0.93	0.22	1.19	2.33	1.15	2.50	0.63	1.02	1.27	0.90

Source: Estimated

Table 7: Decomposition analysis results

Time period	Area effect (%)	Yield effect (%)	Interaction effect (%)
Period 1 (1957-58 to 1986-87)	-54.6	178.59	-23.98
Period 2 (1987-88 to 1996-97)	-183.72	117.39	-33.67
Period 3 (1997-98 to 2006-07)	-198.42	144.57	-46.15
Period 4 (2007-08 to 2022-23)	-127.55	271.73	-44.18
Overall period	-217.25	468.99	-351.71

Source: Estimated

in the area dedicated to rice cultivation. The results are aligned with the findings reported in [10, 18]. On the other hand, the slowdown in the decline of rice cultivation area can be ascribed to governmental interventions such as the Kerala Conservation of Paddy Land and Wetland Act of 2008, along with advancements in farming technologies. This is evident in the Compound Annual Growth Rate (CAGR), which reflects a reduced rate of decline in rice cultivation area after the implementation of these measures. The CAGR for the area under rice cultivation showed an improvement compared to the previous period, aligning with the findings of [23], who highlighted the critical role of legislation in shaping Kerala's agricultural landscape.

4. CONCLUSION

The rice cultivation in Kerala from 1957-58 to 2022-23 presents a clear picture of the significant transformations in the state's agricultural landscape over this extensive period. A critical finding is the dramatic decline in the area under rice cultivation, which fell from 7.66 lakh hectares in 1957-58 to just 1.91 lakh hectares by 2022-23, marking a 75% reduction. This sharp decrease can be attributed to several socio-economic and structural factors that have reshaped Kerala's agricultural priorities.

The decline in rice cultivation in Kerala was primarily driven by the increased demand for land, leading to the conversion of agricultural areas for residential and commercial purposes. This trend was intensified by rural labour shortages, as many shifted to non-agricultural sectors. The labour-intensive nature of rice farming, coupled with rising labour costs, made it less economically viable. Additionally, farmers increasingly switched to high-value cash crops like rubber and coconut, which provided more stable and higher returns with lower labour requirements. This shift not only reduced the rice-growing areas but also transformed rural agricultural practices.

Despite these challenges, the study also reveals an important counter-trend: a steady increase in rice productivity. Over the six decades of the study, rice productivity rose from 1,188 kg per hectare in 1957-58 to 3,108 kg per hectare by 2022-23. This growth in productivity was driven by several factors, including technological advancements, the introduction of high-yielding varieties, improved irrigation techniques, and better crop management practices. However, while productivity gains were impressive, they were insufficient to offset the significant loss of area under cultivation, leading to an overall decline in total rice production. The decline in the cultivated area overshadowed the improvements in yield, resulting in a reduced overall rice output.

The analysis of rice cultivation in Kerala across the four periods reveals distinct trends driven by socio-economic and policy factors. In Period 1 (1957-58 to 1986-87), rice cultivation peaked but declined as land-use shifts started. Period 2 (1986-87 to 1996-97) marked a more severe decline, with steep area losses, particularly in key rice-producing districts, where productivity improvements were insufficient to offset production declines. Period 3 (1996-97 to 2006-07) witnessed the sharpest drop, primarily due to increased demand for land and a shift towards more profitable cash crops. Period 4 (2007-08 to 2022-23) saw a moderated decline largely due to interventions like the Kerala Conservation of Paddy and Wetland Act of 2008, but the overall trend of reduction in rice areas persevered. The periodical comparison highlights that period 3 experienced the sharpest decline, and just after that, period 4 saw a reduction in the decline. This underscores the importance of policy measures and productivity improvements in mitigating the decline of the rice area. It also signifies that the measuresare not fully countered the broader decline in rice cultivation, driven by economic and demographic pressures.

A critical intervention that helped slow down the decline in rice cultivation was the Kerala Conservation of Paddy Land and Wetland Act of 2008. This legislation was designed to protect paddy fields and wetlands from being converted for other uses. The Act was instrumental in reducing the pace of decline in the area under rice. However, despite this legal protection, the overall trend of declining rice area persisted, underscoring the deep-rooted nature of the economic and social factors that drive land-use changes in Kerala. This signifies thatto ensure the sustainability of rice cultivation, future policies must focus on improving land-use management, protecting paddy and wetlands, and implementing market interventions to make rice farming more economically viable.

The research recommends the following policy interventions to reduce the decline in rice cultivation:

1. Strengthen land protection policies: Strengthen enforcement of The Kerala Conversion of Paddy and Wetland Act of 2008 and incentivise farmers to retain paddy fields.
2. Address labour shortages through mechanization: Incentivize Farm Mechanization and provide subsidies and loans for agricultural machinery to reduce labour dependency and increase efficiency.
3. Promote mixed farming: Encourage farmers to grow alternative crops or integrate livestock/fisheries with rice farming for better economic returns.
4. Reform minimum support prices (MSP): Ensure timely procurement and fair prices for rice farmers to improve income security.
5. Promote climate-resilient varieties: Encourage using rice varieties that can withstand erratic weather patterns, such as drought or floods.

REFERENCES

1. USDA [United States Department of Agriculture]. Economic Research Service. 2022. [on-line]. Available: https:// www. ers.usda.gov/topics/crops/rice. [23 July 2024].
2. CGIAR [Consultative Group on International Agricultural Research]. Initiative on Foresight. 2023. [on-line]. Available:https://www.cgiar.org/news. [23 July 2024].
3. Wassmann R, Hien NX, Hoanh CT, Tuong TP.. Sea level rise affecting the Vietnamese Mekong Delta: water elevation in the flood season and implications for rice production. Climatic change, 2004; *66*: pp.89-107.
4. Nageswari R, Chandrasekaran R, Saranraj T. Status of drip irrigation research in rice: A review.*Manag. Strategies for Water Use Efficiency and Micro Irrigated Crops*, 2019: pp.81-92.
5. AmeenA, Raza S. Green revolution: a review. Int. J. Adv. in Sci. Res. 2017; *3*(12): pp.129-137.

6. GulatiA, Roy R, Hussain S. Getting Punjab agriculture back on high growth path: sources, drivers and policy lessons.Indian Council for Research on International Economic Relations 2017: pp. 42.
7. Kannan KP. Agricultural development in an emerging non-agrarian regional economy: Kerala's challenges. Econ. Polit. Wkly. 2011; 46(9):64-70.
8. GOK [Government of Kerala]. Agricultural Statistics 2022-23, Department of Economics and Statistics.2024: p.342.
9. GOK [Government of Kerala]. Agricultural Statistics in Kerala 1975, Department of Economics and Statistics. 1976: p.91.
10. AbrahamMP. Paddy cultivation in Kerala: A trend analysis of area, production and productivity at District Level. 2019: pp. 60.
11. ThomasN, James EJ, George C. Water-related impacts on agriculture due to climate change: a review with reference to Kerala. Sustainability Agri. Food and Environ. Res. 2022; *10*: pp. 10.
12. Gujarati DN, Porter DC, GunasekarS. Basic econometrics Tata McGraw-Hill Education. New Delhi. 2009: pp. 885.
13. Bai J, Perron P. Estimating and testing linear models with multiple structural changes. Econometrica, 1998: pp.47-78.
14. Hazel PB. Instability in Indian foodgrain production (Vol. 30). International Food Policy Research Institute. 1982; 30: pp. 60.
15. Aswani TD, Varghese E. An Evaluation of the Structural Change of the Agrarian Sector in Kerala. *Sciences (IJMTS)*, 2023; *8*(1): pp.99-109.
16. FrankeRW, Chasin BH. Kerala State, India: radical reform as development. Int. J. Health Serv. 1992; *22*(1): pp.139-156.
17. Shindu PS, Govindaru V.Spatio-temporal change of crop diversification in Kerala: An economic review. In Landscape ecology and water management: Proceedings of IGU Rohtak Conference.2014; *2*: pp. 129-136.
18. KumarBM, Kunhamu TK. Ecological and historical perspectives of rice cultivation in Kerala: a synthesis. 2021: 241-261.
19. GOK [Government of Kerala]. Economic review 2023. Kerala State Planning Board. 2023: pp.654.
20. Raj PN, Azeez PA. Real estate and agricultural wetlands in Kerala. *Econ. Polit. Wkly*. 2009: 63-66.
21. GOK [Government of Kerala]. Kerala Conservation of Paddy Land and WetlandAct, 2008. 2008. [on-line]. Available:http://envt.kerala.gov.in/wp-content/uploads [20 August 2024].
22. MoSPI [Ministry of Statistics and Programme Implementation]. Situational assessment of agricultural households and land holdings in rural India. National Statistics Office. 2021.
23. LekshmiUD, Venkataramana MN. Growth and instability analysis of area, production and productivity of paddy in Kerala, with Special Reference to "The Kerala Conservation of Paddy Land and Wetland Act, 2008." *Int. J. Agric. Environ.Biotechnol.* 2020; *13*(1): 93-98.