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Rainfall Fluctuations and Land Resource Transformation in Tirunelveli District, Tamil Nadu: Evidence from Secondary Data

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Abstract- Rainfall variability is one of the important aspects of agricultural production and land use like rain shadow regions. The study analyses the fluctuation of rainfall and land use pattern in Tirunelveli district of Tamil Nadu by considering 2016–2025. The data has been collected from the Secondary sources of the Department of Economics and Statistics, Tirunelveli district. The study looked at actual rainfall, normal rainfall, and deviation of rainfall. It also studied the nine-fold land utilization pattern and Total Common Property Resources (CPR), Total Private Property Resources (PPR). The data has been analysed by using descriptive statistics, deviation of rainfall analysis, and Wilcoxon Signed-Rank Test to check the significant difference between actual and normal rainfall of the study area. The study found significant deviations in terms of yearly rainfall with a range of 383 mm to 1,931 mm and it varied from −54.67 per cent to 142.59 per cent during 2016–2025. The test result also reported that there is a significant difference between actual and normal rainfall for the study area ($p = 0.047$). Land use pattern analysis also reported a significant change in forest land, current fallows, and net area sown whereas permanent pasture and other land uses were stable and had a significant degree of variation during 2016–2025. Total CPR and PPR also showed significant variations during the study period. The study concluded that rainfall fluctuation has influenced agricultural production and land use pattern in Tirunelveli district. The study suggested that there is a need for improved water harvesting activities, conservation of CPR, climate-resilient crop patterns, and site-specific land use to cope up with the changing climate in the study area.

Keywords- Rainfall Variability; Land Resource Transformation; Land Use; Common Property Resources; Private Property Resources; Tirunelveli District; Tamil Nadu; Climate Variability

I. Introduction

Rainfall is one of the most significant climatic parameters that influence agricultural production, water availability, and land use. Differences in the amount and time of rainfall affect the moisture regime of the soil, agricultural practices and technologies, the number of irrigated fields, and the productivity of the land. IPCC (2022) reports that changes in hydrological cycles and regimes, such as increased rainfall variability, droughts, and flood events, have affected agricultural production and water potential in several regions.

These variations are especially relevant for areas highly dependent on rainfall. Land resources and use are directly linked to climatic parameters through the impact of precipitation on land resource availability and use. IPCC (2019) highlights the close

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connection between climate variability and land-use changes and stresses that they are two key factors that can affect water resources, the biogeochemical and ecological functions of the land, as well as agricultural production. Precipitation changes impact agricultural production by altering the risks of runoff, flooding, and erosion and affecting the moisture regime of the soil. On the other hand, insufficient rainfall impacts the use of agricultural land by leading to the fallowing of farmland and changing the crop growing system. Therefore, the current paper focuses on the relationship between rainfall changes and the use of land resource categories.

The impact of rainfall changes in the Indian region is significant for the country's agriculture and rural resources. In this regard, the current paper aims to explore the impact of rainfall changes on agriculture and land use in Tamil Nadu. The existing literature confirms the significance of rainfall variability for the crop planning in Tamil Nadu. Kokilavani et al. (2016) analyze 38 years of rainfall data of Tirunelveli district, which is part of Tamil Nadu, and identify spatial and temporal trends of rainfall variability that are relevant for agricultural production. On the other hand, Tamil Nadu studies confirm the significance of rainfall variability for agricultural production, with several scholars reporting that changes in rainfall regimes and intensities are some of the factors that impact crop yield and production risks (Rao et al.).

Thus, Tirunelveli district is an excellent example of how rainfall variability impacts local agricultural production. The district is characterized by a relatively dry climate, with the Agasthiyamalai hills creating a rain shadow that results in significant variations in rainfall amounts across the district. Apart from the local challenges, Tirunelveli district faces climate change impacts related to monsoon failures that affect both agriculture and the local economy. The Government of Tamil Nadu provides information on rainfall received, the number of rainy days, and the normal amount of rainfall for Tirunelveli district in terms of percentage deviations.

Changes in rainfall amounts and distribution can affect the areal extent of land resource classes. In turn, changes in the land resource classes – net area sown, current fallows, other fallows, permanent pastures, cultivable waste, and land used for other purposes – affect the hydrological regime and water resources. The analysis of the river basin in India confirmed the significant impact of both climate change and land use changes on water resources, with rainfall changes being the main driver of change. Therefore, in order to understand the relationship between climate change and land use/cover changes, it is necessary to study the changes in the distribution of rainfall amounts.

Against this background, this paper entitled "Rainfall Fluctuations and Land Resource Transformation in Tirunelveli District, Tamil Nadu: Evidence from Secondary Data" explores the characteristics of rainfall changes and their impact on land resource use in Tirunelveli district. This paper utilizes secondary data related to rainfall changes and uses statistical methods to identify temporal trends. The current paper focuses on analyzing land resource transformation in Tirunelveli district in association with changes in the amount of rainfall to identify the trends of change in the two aspects.

The findings of the current research contribute to a better understanding of the patterns of land resource use transformation in Tirunelveli district and provide a foundation for

future studies that address the challenges associated with climate change and agriculture in the area.

Rainfall variation is one of the important factors as changes in rainfall pattern affect agricultural activities and utilization of land resources. In Tirunelveli district, a noticeable change in rainfall and land use was witnessed during 2016–2025. However, change in rainfall pattern and land resources utilization was not studied together in this region previously. Therefore, in the current study, an attempt was made to monitor the fluctuation of rainfall and transformation of land resources in Tirunelveli district between 2016 and 2025.

Against this background, the present study analysed the pattern and variability of actual and normal rainfall in Tirunelveli district for the period of 2016–2025. The study aims to analyse the change in the nine–fold land use pattern and status of CPRs and PPRs and to examine the significant difference between the actual and normal rainfall in the study area for 2016–2025 using the Wilcoxon Signed-Rank Test.

II. Review of Literature

1. **Dev, S. M. (2011)** explored the relationships between climate change, rural livelihood, agriculture, and food security in the Asia-Pacific region, with a focus on the vulnerability of rural populations whose livelihoods were highly dependent on agriculture. Over sixty per cent of the population in the Asia-Pacific region were dependent, directly or indirectly, on agriculture for their livelihoods, making them highly vulnerable to climate change impacts such as temperature rise, changes in rainfall regimes, and extreme weather events. The objective of the study was to assess threats and vulnerabilities to livelihood assets and agricultural systems that could be expected in the Asia-Pacific region by considering exposure, sensitivity, and adaptive capacity to climate change. The study also sought to establish the impact of climate change on agriculture, food security, adaptation, and mitigation.

The study used secondary data analysis to examine regional socio-economic and climatic information, past research findings, IPCC scenarios, and vulnerability indicators to assess the potential impact of climate change on livelihoods and agriculture in the Asia-Pacific region. The study established that temperature changes in most of Asia had been rising at a rate of less than 1°C to 3°C per century. In addition, the study also established that rainfall was highly variable across Asia. The study also established that the livelihoods of the people in mountainous, arid, and semi-arid, coastal, forest, and island regions of Asia were highly vulnerable to climate change because of the low adaptive capacity of the regions.

The study also predicted that crop yields in East and Southeast Asia would increase by up to twenty per cent by the middle of this century, while crop yields in Central and South Asia were predicted to decrease by thirty per cent by the same time. Climate change was also predicted to increase the number of undernourished children in the Asia-Pacific region by fourteen to sixteen per cent by 2050 if CO_2 fertilisation was not considered. In 2000, agriculture was responsible for thirteen per cent of greenhouse gas emissions, while agriculture and land-use changes were responsible for thirty per cent of greenhouse gas emissions. The study therefore concluded that the rural livelihoods

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of the Asia-Pacific region were highly vulnerable to climate change and recommended that adaptation to climate change be reinforced at the community level while promoting agricultural resilience, sustainable resource use, and adaptation and mitigation strategies at the national level.

2. **Pradhan, P. (2025)** explored the effect of climate change on rural livelihood security in India through a qualitative, descriptive and analytical study using secondary sources of information. The study established that most Indians live in rural areas and rely on climate-sensitive activities for their livelihood. Further, the statistics showed that India's mean annual temperature had risen by 0.7 o C and exceeded 45 o C in some places, threatening food production, employment, income and food security. Thus, the article highlights the urgent need to address the impact of climate change on vulnerable groups including small and marginal farmers, women, landless labourers, and tribal populations as they lack the resources to adapt to climate change. Pradhan recommends adaptation measures that are responsive, gender-sensitive and context-specific to enhance resilience and improve livelihood security in rural India.

III. Research Gap

The previous analysis on Tirunelveli district assessed the changes in rainfall and nine-fold land utilisation in 2016-2025 by applying the statistical analysis methods and Wilcoxon Signed-Rank test. However, it mainly focused on separate aspects of rainfall patterns or land resources, and therefore there were some limitations in determining the relationships between them and livelihood activities. Specifically, the previous analysis did not adequately explore the relationships between rainfall variability, permanent pasture, common property resources, private property resources, and livestock-dependent livelihood activities. Thus, the current research aims to fill this gap by investigating the linkages between rainfall and land resources and analysing the trends of rural livelihood resources in Tirunelveli district for the period of 2016-2025.

IV. Materials and Methods

The study was conducted in Tirunelveli district of Tamil Nadu with a special focus on rainfall variability and changes in land resources during 2016–2025. The district was selected for the study due to the close connection between the local agricultural and rural development and the availability of land and rainfall resources. The study entirely relied on secondary data, including the annual rainfall and land-use data gathered over ten years (2016–2025). The data were collected from the Department of Economics and Statistics, Tirunelveli District, in the form of Tirunelveli District Statistical Handbook published in different issues up to 2024–2025.

The variables under consideration were actual rainfall, normal rainfall, and rainfall deviation (%). The deviation was calculated using the following formula:

$$\text{Rainfall Deviation (\%)} = [(\text{Actual Rainfall} - \text{Normal Rainfall})/\text{Normal Rainfall}] \times 100$$

As for the land-use variables, they were classified according to the nine-fold land utilisation classification, including Forest, Barren and Uncultivable Land (BUL), Land under Non-Agricultural Uses (LNAL), Culturable Waste Land (CW), Permanent

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Pasture (PP), Land under Miscellaneous Tree Crops, Current Fallows (CF), Other than Current Fallows (OFL), and Net Area Sown (NAS).In addition, the study considered two aggregated indicators of land resources, namely, Total Common Property Resources (CPR) and Total Private Property Resources (PPR).

The data were analysed using descriptive and non-parametric statistics. First, the data were grouped according to years, and descriptive statistics, including the minimum, maximum, mean, and standard deviation, were calculated to highlight the trends in the variables under consideration over the ten-year period. Next, to test whether the actual rainfall was significantly different from the normal one, a Wilcoxon Signed-Rank Test was used. The choice of this test was justified by the nature of the data, which is paired data. The level of significance was set at 5 per cent ($p < 0.05$). The test results revealed that the actual rainfall significantly differed from the normal rainfall over the ten-year period ($p = 0.047$). Thus, the study used rainfall deviation analysis, descriptive statistics, and the Wilcoxon Signed-Rank Test to assess the changes in rainfall and land resources in Tirunelveli district.

V. Result and Discussion

Table: 1 Nine-Fold Land Utilisation in Tirunelveli District (2010–2025)

Year	Forest	Barren and Uncultivable land	Non Agri Cultural Uses	Cultivable Waste Land	Permanent Pasture	Land under Misc.tree crops	Current Fallows	Other than current fallows	Net area sown	Geographical area
2016	127758 (18.9)	30027 (4.4)	103168 (15.3)	35272 (5.2)	5156 (0.8)	8528 (1.3)	17964 (2.7)	172890 (25.6)	175087 (25.9)	675850
2017	127758 (18.9)	30027 (4.4)	103179 (15.3)	34720 (5.1)	5156 (0.8)	8538 (1.3)	62065 (9.2)	168966 (25.0)	135422 (20.0)	675850
2018	127758 (18.9)	30027 (4.4)	103183 (15.3)	34466 (5.1)	5156 (0.8)	8656 (1.3)	31684 (4.7)	176647 (26.1)	158273 (23.4)	675850
2019	83758 (21.6)	23787 (6.1)	62442 (16.1)	25232 (6.5)	4124 (1.1)	6810 (1.8)	10865 (2.8)	111361 (28.7)	59227 (15.3)	387606
2020	83758 (21.6)	23787 (6.1)	62442 (16.1)	25232 (6.5)	4124 (1.1)	6810 (1.8)	6800 (1.8)	108219 (27.9)	66434 (17.1)	387606
2021	83758 (21.6)	23787 (6.1)	62442 (16.1)	25232 (6.5)	4124 (1.1)	6810 (1.8)	8868 (2.3)	105029 (27.1)	67557 (17.4)	387606
2022	83758 (21.6)	23787 (6.1)	62442 (16.1)	25232 (6.5)	4124 (1.1)	6810 (1.8)	7689 (2.0)	102558 (26.5)	71207 (18.4)	387606
2023	83758 (21.6)	23787 (6.1)	62442 (16.1)	25232 (6.5)	4124 (1.1)	6773 (1.8)	18111 (4.7)	103575 (26.7)	59805 (15.4)	387606
2024	83758 (21.6)	23787 (6.1)	62442 (16.1)	25152 (6.5)	4112 (1.1)	6773 (1.8)	11801 (3.0)	102732 (26.5)	67050 (17.3)	387606
2025	83758 (21.6)	23784 (6.1)	62442 (16.1)	25148 (6.5)	4112 (1.1)	6815 (1.8)	10619 (2.7)	105116 (27.1)	65813 (17)	387606

Source: Department of Economics and Statistics, Tirunelveli District, Tirunelveli District Statistical Handbook in various issues up to 2024-2025

The table 1 below presents the nine-fold land utilisation pattern in Tirunelveli district for the period 2016–2025 indicates the changes that occurred in the area. It is noticeable

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that forest area was constant at 127,758 ha for the period 2016–2018 and dropped to 83,758 ha in 2019 and remained the same until 2025. Net area sown showed wide variations, recording the highest value of 175,087 ha in 2016 and dropping to 59,227 ha in 2019 before improving slightly in the following years. Current fallow lands also showed considerable variations as the area put fallow for a short period was cultivated. Other categories of land use including barren land, non-agricultural lands, and permanent pasture were stable throughout the period, especially after 2019. Thus, based on the data presented in the table, it can be concluded that there were large-scale variations in the area of cultivated lands and fallow lands while other categories of land use were stable or showed minimal variations.

Table: 2 Year-wise Actual Rainfall, Normal Rainfall and Percentage Deviation, 2016–2025

Year	Actual	Normal	Rainfall Deviation
2016	1333	845	57.69
2017	383	845	-54.67
2018	989	845	17.01
2019	969	845	14.65
2020	1094	820	33.45
2021	1255	822	52.68
2022	1200	786	52.75
2023	674	796	-15.32
2024	1931	796	142.59
2025	1914	796	140.55

Source: Department of Economics and Statistics, Tirunelveli District, Tirunelveli District Statistical Handbook in various issues up to 2024-2025

Table 2 presents the rainfall pattern in Tirunelveli District during 2016-2025 which shows that there was not much difference between years in terms of rainfall. It was observed that the annual rainfall varied from low value (383mm) in 2017 to a high value (1931mm) in 2024. The years 2017 had recorded a deficiency of -54.67 % while the year 2023 had recorded a rainfall 15.32% below average. Contrary, other years had a surplus rainfall with large positive deviations, especially, in 2024 (142.59%) and 2025 (140.55% deviation). It can be concluded that there has been an increase in rainfall variability over the study area which may affect agricultural activities and the rural community.

Table:3 Wilcoxon Signed-Rank Test for Actual and Normal Rainfall

Variables Compared	Test Statistic (Z)	Sig.(2-tailed)	Decision
Actual vs. Normal	-	0.047	Reject H_0

Source: Department of Economics and Statistics, Tirunelveli District, Tirunelveli District Statistical Handbook in various issues up to 2024-2025

The table 3 shows the Wilcoxon Signed-Rank Test reveals that there is a significant difference between actual and normal rainfall ($p = 0.047 < 0.05$). Thus, the null

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hypothesis is rejected, which implies that actual rainfall was significantly different from normal rainfall; therefore, there was a large variation in rainfall during the period.

Table 4: Descriptive Statistics of Rainfall Variability and Land Resource Variables in Tirunelveli District, 2016–2025

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Actual	10	383	1931	1174.08	484.326
Normal	10	786	845	819.49	24.635
Rainfall Deviations	10	-54.67	142.59	44.1370	61.76581
Forest	10	83758	127758	96958.14	21253.924
BUL	10	23784	30027	25658.55	3014.518
LNAL	10	62442	103183	74662.27	19676.805
CW	10	25148	35272	28091.82	4646.604
Pasture	10	4112	5156	4431.24	500.152
Miscellaneuos	10	6773	8656	7332.42	857.563
CF	10	6800	62065	18646.50	16943.650
OFL	10	102558	176647	125709.18	32675.636
NAS	10	59227	175087	92587.31	45067.795
Total CPR	10	239459	374054	280848.93	62011.765
Total PPR	10	139344	309204	193228.49	77366.555
Valid N (listwise)	10				

Source: Department of Economics and Statistics, Tirunelveli District, Tirunelveli District Statistical Handbook in various issues up to 2024-2025

Table 4 reports the descriptive statistics of rainfall variability and land resources in Tirunelveli District for 2016–2025. The actual rainfall had a large range from 458.4 to 2631.5 with a mean value of 1174.08, while the normal rainfall was comparatively lower with a large range from 458.4 to 2280.3 and a mean value of 819.49. Actual rainfall had a deviation from normal rainfall from -54.67% to 142.59%. It can be observed that the Current Fallows, Net Area Sown, Total CPR, and Total PPR land resources had a higher degree of fluctuation. A mean value of Total CPR was 280848.93, whereas the Total PPR was 193228.49, which indicated the changes in common land resources for the study period.

Findings:

The present study revealed that there was a tremendous difference in rainfall in Tirunelveli District in the period 2016–2025. The amount of rainfall varied from a minimum of 383 mm in 2017 to a maximum of 1931 mm in 2024. Moreover, the difference between the actual and normal rainfall was found to be highly significant (Wilcoxon Signed-Rank Test, $p = 0.047$). The deviation of rainfall varied from −54.67 to 142.59%. There was also a significant change in the forest cover, current fallows, and net area sown, while permanent pasture, and a few other land-use categories remained stable. The total CPR and PPR were also found to vary significantly in the study period.

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Suggestion:
1. Fluctuation in rainfall must be taken care of.
2. Harvesting rainwater and managing it efficiently should be promoted.
3. Common property resources, especially pastures, need to be conserved.
4. Farmers should be advised to grow crops which are less susceptible to irregularities in the rainfall pattern.
5. There is a need to plan the land resource use in accordance with the anticipated change in rainfall at the local level.

VI. Conclusion

The study concluded that there was a significant inconsistency in the amount of rainfall received by Tirunelveli district from 2016 to 2025. The inconsistency was associated with a great difference between the observed and normal rainfall. The changing pattern of rainfall was closely linked to changes in the number of cultivated and fallow lands as other land resource use/cover uses were stable throughout the years. The conclusion further emphasizes the need to promote climate-smart agriculture, adaptive strategies in managing common resources, and improved water management practices to achieve food security in Tirunelveli district.

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