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Analysis of crop concentration and rainfall in drought-prone areas of Sri Sathya Sai district, Rayalaseema region, Andhra Pradesh: A geo-informatics technique

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Abstract
The agricultural landscape of the Sri Sathya Sai District exhibits significant variability in crop cultivation and rainfall distribution during the 2022-2023 period. Key crops include paddy and groundnut, occupying 6,527 hectares (1.78%) and 204, 268 hectares (55.93%), respectively. Mandals such as Hindupur focus heavily on maize, while Dharmavaram has the largest cultivated area primarily dedicated to groundnut. Rainfall patterns are categorized into three ranges: less than 750 mm, 750 to 1000 mm, and over 1000 mm, influencing agricultural productivity. Regions with less than 750 mm, like C.K. Palle and Nallacheruvu, face challenges in crop yield, whereas areas receiving 750 to 1000 mm, such as Roddam and Puttaparthi, support diverse agricultural activities. High rainfall areas, including Hindupur and Amarapuram, present both productivity potential and risks of flooding. The interplay between crop concentration and rainfall underscores the need for tailored agricultural strategies and effective water management to enhance productivity and sustainability. This analysis highlights the importance of understanding local conditions for future agricultural planning and development in the district, aiming to optimize crop diversity and food security while addressing the unique climatic challenges faced by different mandals.

Keywords: Crops, precipitation, IMD & GIS

Introduction

Study area

The Sri Sathya Sai District is located between 13°40' and 14°6' North Latitude and 76°88' and 78°30' East Longitude. Ananthapuramu District borders the districts of YSR Kadapa and Chittoor to the north, and the State of Karnataka to the west and southwest. The soil in the area is generally sandy red and reflects typical productivity levels. The place is known for having been previously named Gollapalli and is situated on the banks of the River Chitravathi. The area is also known for having been previously covered by anthills and snake pits. The district covers an area of 7,771 square kilometers. The population of the district is recorded to be 1,840,043 according to the 2011 census. Of the total population of 392,357, 21.32% live in urban locales (fig. 1).

The relationship between crop concentration and rainfall patterns is critical for agricultural science and food security, especially as the global population continues to grow. Crop concentration, which is influenced by soil type, climate, and water availability, reflects how specific crops are distributed across different areas. In regions where rainfall is abundant and well distributed, farmers can cultivate a variety of crops, thereby enhancing biodiversity and resilience. However, in areas with irregular or insufficient rainfall, there is often a focus on drought-resistant crops, which reduces diversity and negatively impacts local economies. As climate change continues to alter rainfall patterns, it is essential to understand this relationship to develop sustainable agricultural practices, optimize crop selection, and improve irrigation strategies. This understanding is crucial for ensuring food production and environmental sustainability.

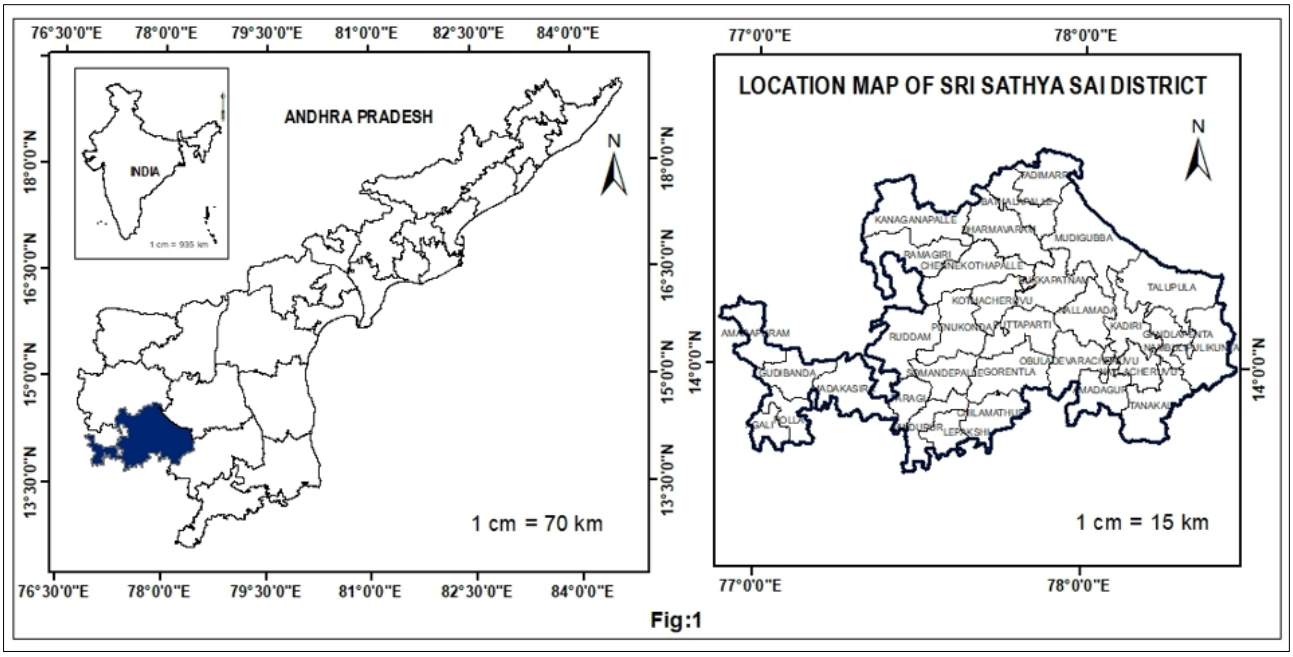

Fig 1: Location Map of Sri Sathya Sai District, Andhra Pradesh (Study Area)

Objectives

1. To study crop concentration from 2022 to 2023.
2. To examine the distribution of rainfall (in mm) from 2022 to 2023.
3. To compare crop concentration and rainfall (in mm) from 2022 to 2023.

Methodology & Data collection

This study used secondary data from authoritative sources, primarily the Handbook of Statistics published by the Directorate of Economics and Statistics, Government of Andhra Pradesh. Data analysis was conducted at the mandal level.

1. **Crop Concentration:** Crop concentration assesses the proportion of a specific crop cultivated in a mandal relative to the total area of that crop within the district, as measured in this study.
2. **Rainfall Data:** Rainfall data, measured in millimeters (mm), was obtained from the Directorate of Economics and Statistics, Government of Andhra Pradesh, and is presented on a mandal-wise basis. The analysis focuses on rainfall distribution in the mandal for the year 2022-2023.

Software: ArcGIS 10.3 and relevant statistical tools were utilized for data analysis.

Result & Discussion

Table 1: Sri Sathya Sai District, Mandal-wise Area under Major Crops (in Hectares) and Percentage Distribution of Crop Concentration (in%): 2022-2023

S. No.	Name of the Mandal	Paddy		Jowar		Bajra		Maiz		Ragi		Horse-gram		Red-gram		Gross area sown
		Hec	%	Hec	%	Hec	%	Hec	%	Hec	%	Hec	%	Hec	%	Hec
1	Dharmavaram	446	2.29	27	0.13	0	0	60	0.30	0	0	11	0.05	1386	7.14	19411
2	Bathalapalle	275	1.88	2	0.01	0	0	39	0.26	0	0	41	0.28	2711	18.56	14606
3	Tadimarri	256	1.68	20	0.13	0	0	62	0.40	3	0.01	23	0.15	866	5.71	15161
4	Mudigubba	118	0.43	2	0.00	18	0.06	107	0.39	4	0.01	10	0.03	4605	17.05	27004
5	Kanaganapalle	122	0.43	7	0.02	0	0	12	0.04	0	0	4	0.01	3616	12.75	28353
6	C.K.Palle	173	0.90	0	0	0	0	72	0.37	0	0	1	0.00	949	4.94	19184
7	Ramagiri	56	0.26	6	0.02	0	0	145	0.69	0	0	40	0.19	3343	16.01	20872
8	Talupula	451	3.52	3	0.02	4	0.03	19	0.14	3	0.02	7	0.05	2508	19.57	12812
9	N.P.Kunta	192	1.74	0	0	12	0.10	21	0.19	3	0.02	44	0.40	1819	16.55	10989
10	Gandlapenta	191	2.30	2	0.02	47	0.56	20	0.24	1	0.01	6	0.07	1942	23.45	8281
11	Kadiri	250	2.89	8	0.09	139	1.61	196	2.27	7	0.08	44	0.50	1894	21.94	8631
12	Nallacheruvu	133	2.33	3	0.05	19	0.33	124	2.17	6	0.10	4	0.07	216	3.79	5694
13	Tanakal	208	1.86	10	0.08	130	1.16	817	7.33	9	0.08	33	0.29	378	3.39	11131
14	Amadagur	94	1.16	0	0	98	1.21	232	2.87	1	0.01	10	0.12	634	7.84	8080
15	O.D. Cheruvu	198	1.98	10	0.10	251	2.51	442	4.43	5	0.05	39	0.39	358	3.58	9977
16	Gorantla	238	1.73	9	0.06	1	0.00	1693	12.31	19	0.13	18	0.13	954	6.94	13743
17	Nallamada	227	1.81	8	0.06	69	0.55	320	2.55	3	0.02	65	0.51	604	4.82	12514
18	Bukkapatnam	532	5.27	15	0.14	1	0.00	174	1.72	5	0.04	18	0.17	1045	10.3	10092
19	Kothacheruvu	355	3.76	17	0.18	0	0	1148	12.18	6	0.06	127	1.34	352	3.73	9424
20	Puttaparthi	679	7.67	6	0.06	9	0.10	382	4.31	10	0.11	49	0.55	1933	21.84	8848
21	Roddam	173	1.31	30	0.22	1	0.00	2539	19.28	57	0.43	158	1.20	3582	27.21	13164
22	Madakasira	99	0.95	15	0.14	2	0.01	1624	15.67	228	2.20	190	1.83	1040	10.04	10359

23	Amarapuram	21	0.17	182	1.51	0	0	323	2.68	520	4.32	134	1.11	544	4.52	12012
24	Gudibanda	156	1.56	99	0.99	2	0.02	636	6.37	892	8.94	485	4.86	429	4.30	9970
25	Rolla	21	0.28	182	2.45	0	0	677	9.11	641	8.63	119	1.60	414	5.57	7425
26	Agali	8	0.11	14	0.20	1	0.01	701	10.31	1565	23.02	104	1.53	84	1.23	6797
27	Parigi	78	1.78	68	1.55	0	0	2644	60.58	60	1.37	27	0.61	109	2.49	4364
28	Penukonda	237	5.04	5	0.10	3	0.06	1236	26.29	19	0.40	138	2.93	284	6.04	4700
29	Somandepalle	183	3.81	8	0.16	8	0.16	1830	38.12	140	2.91	22	0.45	590	12.29	4800
30	Hindupur	109	2.41	4	0.08	0	0	3225	71.49	50	1.10	7	0.15	68	1.50	4511
31	Lepakshi	66	1.35	12	0.24	0	0	2420	49.49	37	0.75	40	0.81	165	3.37	4889
32	Chilamathur	182	2.46	7	0.09	1	0.01	4192	56.82	76	1.03	35	0.47	193	2.61	7377
Total		6527	1.78	781	0.21	816	0.22	28132	7.70	4370	1.19	2053	0.56	39615	10.84	365175

Directorate of Economics and Statistics, Government of Andhra Pradesh (2022-2023); computed and analyzed by the researcher

Paddy

Puttaparthi leads paddy cultivation in the district with 679 hectares (7.67%), followed by Bukkapatnam (532 hectares, 5.27%) and Penukonda (237 hectares, 5.04%), highlighting their agricultural significance. In contrast, mandals like Agali (8 hectares, 0.11%) and Amarapuram (21 hectares, 0.17%) show minimal cultivation, likely due to limitations in soil quality and water availability. Overall, the distribution of paddy farming across the Sri Sathya Sai district reflects a diverse agricultural landscape, with varying levels of engagement influenced by local practices and resources.

Jowar

Amarapuram leads in Jowar cultivation with 182 hectares, accounting for 1.515% of its agricultural area, while Rolla matches this area but has a higher percentage at 2.451%. Other mandals like Gudibanda (99 hectares, 0.99%) and Parigi (68 hectares, 1.558%) show moderate Jowar cultivation, whereas Chennekothapalle and N.P. Kunta report no Jowar fields, indicating gaps in agricultural diversity. Lower percentages in Roddam (30 hectares, 0.227%) and Kadiri (8 hectares, 0.092%) suggest limited adoption of Jowar. This variability highlights the need for targeted agricultural policies to enhance crop diversity and food security in the Sri Sathya Sai District.

Bajra

Bajra cultivation in the Sri Sathya Sai District is unevenly distributed across mandals. Notably, several mandals, such as Dharmavaram and Bathalapalle, report zero area under Bajra, while O.D. Cheruvu leads with 251 units (2.515% of its total area). Kadiri and Tanakal also show significant areas of 139 and 130 units, respectively. In contrast, many mandals contribute minimally, with areas as low as 1 unit. This disparity may be influenced by factors like soil type, water availability, and local agricultural practices, highlighting the need for further investigation into enhancing Bajra production in less active mandals.

Maize

Chilamathur leads in maize cultivation within the Sri Sathya Sai District, covering 4,192 hectares (56.82% of its agricultural land), followed by Hindupur (3,225 hectares, 71.49%) and Lepakshi (2,420 hectares, 49.49%). In contrast, Kanaganapalle has only 12 hectares (0.04%), indicating significant disparities influenced by factors like soil fertility and water availability. Mandals like Roddam (2,539 hectares, 19.28%) and Madakasira (1,624 hectares, 15.67%) also play vital roles in maize production. This data highlights the diverse agricultural practices across mandals, essential for policymakers focused on enhancing maize production and food security in the region.

Ragi

Ragi cultivation in the Sri Sathya Sai District shows significant variation among mandals. Agali leads with 1,565 acres (23.02% of the total cultivated area), indicating favorable conditions for Ragi farming. Gudibanda and Rolla follow with 892 acres (8.94%) and 641 acres (8.63%), respectively. In contrast, mandals like Dharmavaram and Bathalapalle report no Ragi cultivation, suggesting unsuitable conditions or lack of interest. Many mandals have less than 1% of their area dedicated to Ragi, highlighting an uneven distribution of this important crop. This distribution reflects agricultural practices and potential for crop diversification, warranting further exploration for enhanced food security and sustainability.

Horse gram

The data on horsegram cultivation reveals significant variability across mandals, with Gudibanda leading at 485 hectares (4.86% of its agricultural area), followed by Madakasira (190 hectares, 1.83%) and Roddam (158 hectares, 1.20%). In contrast, some mandals like Chennekothapalle and Kanaganapalle show minimal cultivation, indicating possible limitations in soil conditions or market demand. Moderate cultivation is seen in N.P. Kunta and Kadiri (44 hectares each), while Penukonda and Rolla demonstrate stronger engagement with 138 hectares (2.93%) and 119 hectares (1.60%), respectively. This diverse landscape highlights the varying levels of commitment to horsegram farming and informs future agricultural strategies.

Red gram

Roddam mandal leads in Redgram cultivation with 3,582 hectares, accounting for 27.21% of the region's total area, indicating favorable conditions or strong demand. Gandlapenta and Kadiri follow with 1,942 hectares (23.45%) and 1,894 hectares (21.94%), respectively. Conversely, Agali and Hindupur have minimal cultivation, with only 84 hectares (1.23%) and 68 hectares (1.50%), possibly due to less favorable conditions or market preferences. This diverse distribution highlights the need for targeted agricultural policies to enhance Redgram production and support local farmers.

Table 2: Sri Sathya Sai District, Mandal-wise Area under Major Crops (in Hectares) and Percentage Distribution of Crop Concentration (in%): 2022-2023

S. No.	Name of the Mandal	Total Pulses		Chilies		Total Cotton		Groundnut		Sunflower		Total Oil seeds		Gross area sown
		Hec	%	Hec	%	Hec	%	Hec	%	Hec	%	Hec	%	Hec
1	Dharmavaram	1437	7.40	6	0.03	96	0.49	13670	70.42	241	1.24	14011	72.18	19411
2	Bathalapalle	2776	19.00	3	0.02	2	0.013	7896	54.06	28	0.19	8111	55.53	14606
3	Tadimarri	966	6.37	8	0.05	9	0.059	8184	53.98	48	0.31	8346	55.04	15161
4	Mudigubba	4781	17.70	0	0	131	0.485	18311	67.80	112	0.41	18476	68.41	27004
5	Kanaganapalle	3624	12.78	33	0.11	347	1.223	16890	59.57	15	0.05	19653	69.31	28353
6	C.K.Palle	952	4.962	10	0.05	8	0.041	15462	80.59	7	0.03	15501	80.80	19184
7	Ramagiri	3602	17.25	49	0.23	113	0.541	14150	67.79	25	0.11	14701	70.43	20872
8	Talupula	2601	20.30	0	0	38	0.296	7704	60.13	131	1.02	7839	61.18	12812
9	N.P.Kunta	1874	17.05	0	0	70	0.637	7747	70.49	58	0.52	7823	71.18	10989
10	Gandlapenta	1955	23.60	0	0	3	0.036	4962	59.92	69	0.83	5039	60.85	8281
11	Kadiri	1953	22.62	0	0	2	0.023	4678	54.2	215	2.49	4903	56.80	8631
12	Nallacheruvu	226	3.96	0	0	1	0.017	4094	71.9	102	1.79	4196	73.69	5694
13	Tanakal	434	3.89	1	0.00	12	0.107	6008	53.97	160	1.43	6178	55.50	11131
14	Amadagur	647	8.00	0	0	12	0.148	6019	74.49	169	2.09	6194	76.65	8080
15	O.D.Cheruvu	399	3.99	0	0	0	0	7209	72.25	418	4.18	7631	76.48	9977
16	Gorantla	974	7.08	1	0.00	0	0	10236	74.48	17	0.12	10263	74.67	13743
17	Nallamada	687	5.48	0	0	7	0.055	9805	78.35	279	2.22	10088	80.61	12514
18	Bukkapatnam	1069	10.59	0	0	13	0.128	5737	56.84	267	2.64	6015	59.60	10092
19	Kothacheruvu	495	5.25	7	0.07	29	0.307	5620	59.63	159	1.68	5809	61.64	9424
20	Puttaparthi	1989	22.48	1	0.01	19	0.214	4783	54.05	53	0.59	4842	54.72	8848
21	Roddam	4798	36.44	354	2.68	1368	10.39	616	4.679	183	1.39	1908	14.49	13164
22	Madakasira	1280	12.35	104	1.00	800	7.72	3981	38.43	100	0.96	4140	39.96	10359
23	Amarapuram	680	5.66	361	3.00	1386	11.53	6118	50.93	21	0.17	6183	51.47	12012
24	Gudibanda	920	9.22	345	3.46	500	5.01	4344	43.57	31	0.31	4470	44.83	9970
25	Rolla	538	7.24	70	0.94	343	4.61	3514	47.32	16	0.21	3632	48.91	7425
26	Agali	194	2.85	33	0.48	354	5.20	2248	33.07	15	0.22	2340	34.42	6797
27	Parigi	196	4.49	142	3.25	91	2.08	213	4.88	14	0.32	242	5.545	4364
28	Penukonda	771	16.40	64	1.36	154	3.27	723	15.38	84	1.78	900	19.14	4700
29	Somandepalle	621	12.93	175	3.64	115	2.39	846	17.62	10	0.20	903	18.81	4800
30	Hindupur	77	1.70	55	1.21	13	0.28	140	3.10	42	0.93	208	4.61	4511
31	Lepakshi	223	4.56	51	1.04	10	0.20	693	14.17	29	0.59	758	15.50	4889
32	Chilamathur	236	3.19	33	0.44	8	0.10	1667	22.59	60	0.81	1743	23.62	7377
Total		43975	12.04	1906	0.52	6054	1.65	204268	55.93	3178	0.87	213046	58.34	365175

Directorate of Economics and Statistics, Government of Andhra Pradesh (2022-2023); computed and analyzed by the researcher

Total pulses

The data highlights significant variability in pulse farming across mandals, with Roddam leading at 4,798 hectares (36.45% of total cultivation), indicating strong support for pulse production. Gandlapenta and Kadiri follow with 1,955 hectares (23.61%) and 1,953 hectares (22.63%), respectively, suggesting favorable conditions for pulse farming. In contrast, mandals like Agali and Hindupur show minimal engagement, with only 194 hectares (2.85%) and 77 hectares (1.71%). The overall distribution underscores diverse agricultural practices and the need for tailored strategies to enhance pulse cultivation based on local conditions.

Chillies

Amarapuram leads in chili cultivation with 361 hectares (3.005%), followed closely by Gudibanda with 345 hectares (3.460%). These regions likely benefit from favorable conditions for high yields. In contrast, several mandals, including Mudigubba and Talupula, report no chili cultivation, while Dharmavaram, Bathalapalle, and Tanakal have minimal areas dedicated to it. Roddam and Madakasira also contribute significantly with 354 hectares (2.689%) and 104 hectares (1.00%), respectively. This uneven distribution highlights key areas for potential expansion and support in chili production across the region.

Total Cotton

Roddam and Amarapuram are the leading mandals in cotton cultivation, with areas of 1,368 hectares (10.39%) and 1,386 hectares (11.53%), respectively. Other notable contributors include Madakasira (800 hectares, 7.72%) and Gudibanda (500 hectares, 5.01%). In contrast, some mandals like Nallacheruvu, Bathalapalle, and Kadiri show minimal cotton farming, with areas as small as 1 to 2 hectares. This variation highlights differing agricultural focuses across the region, underscoring the importance of understanding local practices and potential for future development in cotton cultivation.

Total Oil seeds

Chennekothapalle leads in groundnut cultivation, with approximately 80.6% of its agricultural land (15,462 hectares) dedicated to this crop, likely due to favorable conditions or strong market demand. Mudigubba follows closely at 67.8% of its 18,311 hectares. Other mandals like Ramagiri and Nallamada also show significant groundnut farming, while Roddam and Hindupur have much lower percentages (4.68% and 3.10%, respectively), indicating a preference for alternative crops. Overall, the data reveals diverse agricultural practices and highlights the varying reliance on groundnuts across different mandals, suggesting areas for further research into enhancing production in less engaged regions.

Introduction to Rainfall

Rainfall constitutes a fundamental element of the Earth's hydrological cycle, as it involves the precipitation of water in the form of liquid droplets. It is essential for replenishing freshwater resources, sustaining ecosystems, and shaping weather patterns. Rainfall distribution varies considerably across regions and seasons, thereby affecting agriculture, water supply, and climate. Comprehensive understanding of rainfall patterns is critical for effective water resource management and environmental conservation.

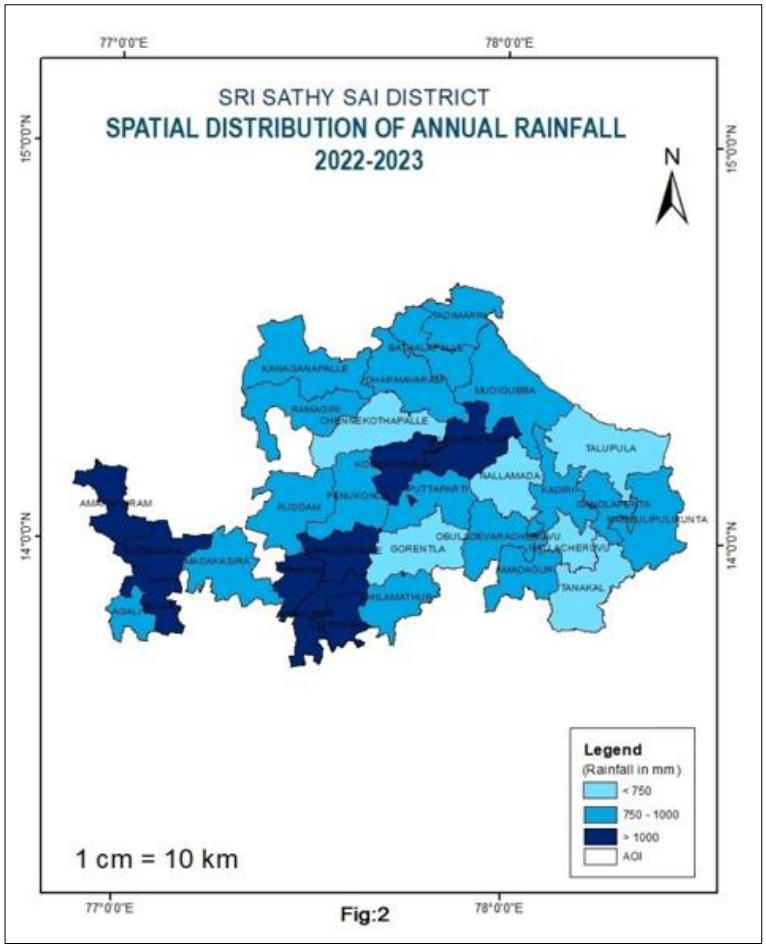

Fig 2: Spatial Distribution of Annual Rainfall in Sri Sathya Sai District, 2022-2023

Spatial Distribution of Annual Rainfall in 2022-2023

The spatial distribution of rainfall in Sri Sathya Sai District during 2022-23 demonstrates considerable variability across regions, which can be categorized into three distinct rainfall ranges. Areas receiving less than 750 mm of annual rainfall, such as C.K. Palle, Nallacheruvu, Tanakal, Gorantala, Talupula, and Nallamada, are characterized by relatively low precipitation. This limited rainfall is likely to affect agricultural practices and water resource management in these locations.

The rainfall range of 750 to 1000 mm includes a broader array of mandals, such as Madakasira, Roddam, Ramagiri, Kanganpalle, Bathapalle, Dharmavaram, Tadimarri, Penukonda, Chilamatur, Puttaparthi, Mudigubba, N.P. Kunta, Gandlapenta, Kadiri, Amadagur, O.D. Cheruvu, and Agali. Moderate rainfall in these areas provides a more favorable environment for crop cultivation and supports a diverse range of agricultural activities. Rainfall distribution within this range indicates potential for sustainable farming practices, contingent upon the effective implementation of water management strategies (fig. 2).

Regions receiving more than 1000 mm of rainfall include Kothacheruvu, Amarapuram, Gudibanda, Rolla, Parigi, Somandepalle, Hindupur, Lepakshi, and Bukkapatnam. These areas experience high precipitation levels that can significantly enhance agricultural productivity. However, abundant rainfall also introduces challenges such as increased risk of flooding and soil erosion, requiring effective land and water management practices to mitigate these risks.

The spatial distribution of rainfall in Sri Sathya Sai District underscores the necessity for region-specific agricultural strategies and water resource management approaches that address the unique climatic conditions of each area. Recognizing these variations is essential for optimizing agricultural output and promoting sustainable development within the district.

Comparative Analysis of Crop Concentration and Rainfall, 2022-2023

During the agricultural year 2022-2023 in Sri Sathya Sai District, both crop concentration and rainfall distribution exhibited significant variability, influencing agricultural practices across mandals. The total sown area reached 365,175 hectares, with paddy and groundnut as the predominant crops, occupying 6,527 hectares (1.78%) and 204,268 hectares (55.93%), respectively. Mandals such as Hindupur demonstrated a strong focus on maize, while Dharmavaram had the largest cultivated area, primarily dedicated to groundnut.

Rainfall patterns further influenced crop distribution, which can be categorized into three ranges: less than 750 mm, 750 to 1000 mm, and over 1000 mm. Regions with less than 750 mm, such as C.K. Palle and Nallacheruvu, encountered challenges in agricultural productivity. In contrast, areas receiving 750 to 1000 mm, such as Roddam and Puttaparthi, supported a diverse range of crops. Areas with over 1000 mm, including Hindupur and Amarapuram, exhibited high productivity potential but also faced increased flooding risks.

The interplay between crop concentration and rainfall highlights the necessity for tailored agricultural strategies and effective water management to optimize productivity and sustainability in the district. Understanding these dynamics is essential for future agricultural planning and development.

Conclusion

The agricultural landscape of the Sri Sathya Sai District reveals significant variability in crop cultivation across different mandals during the 2022-2023 period. Paddy leads with 6,527 hectares (1.78%), followed by groundnut, which dominates with 204,268 hectares (55.93%). Notable contributors include Hindupur, focused on maize, and Dharmavaram, which has the largest cultivated area primarily for groundnut.

Rainfall distribution plays a crucial role in agricultural practices, categorized into three ranges: less than 750 mm, 750 to 1000 mm, and over 1000 mm. Regions with less than 750 mm, such as C.K. Palle and Nallacheruvu, face challenges in productivity, while those receiving 750 to 1000 mm, like Roddam and Puttaparthi, support diverse crops. Areas with over 1000 mm, including Hindupur and Amarapuram, show high productivity potential but also risk flooding.

Crops like jowar, bajra, maize, ragi, horse gram, red gram, and chillies exhibit varying levels of cultivation, influenced by local conditions such as soil quality and water availability. The uneven distribution of crops highlights the need for targeted agricultural policies to enhance crop diversity and food security.

Overall, the interplay between crop concentration and rainfall underscores the necessity for tailored agricultural strategies and effective water management to optimize productivity and sustainability in the district, informing future agricultural planning and development.

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