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REPORT

Analysis of Land Surface Temperature in Semi-Arid Maharashtra and Telangana

2001 – 2020

Authors-
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About Us

WOTR (Watershed Organisation Trust), established in 1993, is currently working across 9 states of India and has touched over 7.92 M Lives. Over the last 30 years, WOTR has been at the forefront of sustainable development and resilience-building in India's semi-arid regions. Today, WOTR stands as a globally recognised non-profit and think tank.

WOTR emerged from the Indo-German Watershed Development Programme (IGWDP) in 1993, where we pioneered the large-scale mobilisation of community-led watershed development in India. This method enables rural communities to regenerate the landscapes and catchments they live in and catch the rain wherever it falls and use it efficiently and sustainably to transform their lives, their livelihoods and their ecosystems.

Our approach has since then evolved to focus on an Ecosystem-based Adaptation (EbA) strategy. This method sees communities and their wellbeing in the context of a larger natural ecosystem and works to restore the health of the ecosystem by encouraging participatory governance, while contributing to resilient incomes, food security and better adaptive capacity of the local communities. Today, WOTR addresses the whole rural ecosystem as a cohesive entity, through natural resource management, climate resilient agriculture, livelihood diversification, women empowerment, nutrition, health, drinking water and sanitation.

Alongside implementing on-ground solutions, WOTR, through its research and policy arm—the WOTR Centre for Resilience Studies (W-CReS)—works to bridge the gap between science, practice, and policy. The goal is to strengthen the economic resilience of vulnerable communities through the restoration and sustainable management of natural ecosystems.

W-CReS conducts rigorous, transdisciplinary, and applied research, providing grounded insights that inform policy formulation, program design, and adaptive governance. Its core focus lies in enabling people and institutions to respond effectively to climate change impacts on ecosystems, water resources, agriculture, food and nutrition, health, livelihoods, and gender equity. The Centre emphasises low- and no-regret adaptive measures, using a systems dynamics lens to assess their long-term sustainability.

With a diverse team of experts in agriculture, ecology, climate science, hydrology, geology, GIS and remote sensing, and socio-economics, W-CReS also plays a key role in training and capacity building—for both WOTR's teams and external partners. It actively engages in policy advocacy, striving to align field realities with strategic policy actions.

To strengthen science-policy-practice integration, WOTR and W-CReS have formal collaborations with several key institutions, including the India Meteorological Department (IMD), Indian Council for Agricultural Research (ICAR), Central Research Institute for Dryland Agriculture (CRIDA), Indian Institute of Tropical Meteorology (IITM), and two State Agricultural Universities.

About the Authors

Vijay Solanky

Vijay Solanky is a dedicated researcher with extensive experience in geoinformatics, sustainable land management, and natural resource conservation. Serving as Senior Researcher and Thematic Lead in Geoinformatics at the Watershed Organisation Trust (WOTR), Solanky applies cutting-edge geospatial technologies and data-driven methodologies to address land degradation, watershed management, and enhance the resilience of rural communities in semi-arid regions of India.

With expertise in remote sensing, geospatial analysis, and AI/ML applications, Solanky has led key projects that integrate Earth observation data with field-based research to inform policy, improve agricultural practices, and combat climate challenges. The work includes leveraging Sentinel, Landsat, and SAR datasets to analyze soil erosion, crop productivity, land surface temperature changes, and ecosystem restoration impacts. Solanky has also contributed to developing innovative tools such as precision farming advisories, empowering stakeholders across the agricultural and environmental sectors.

Ajit Jadhav

Ajit Jadhav holds a Master's degree in Geography from SP College Pune and a Master's in Geoinformatics from Savitribai Phule Pune University. For the past decade, he has been working as a Research Associate with the Watershed Organisation Trust (WOTR) and the WOTR Centre for Resilience Studies (W-CReS). His expertise lies in the application of GIS and Remote Sensing technologies in watershed development, planning, and monitoring. His work focuses on evaluating the impacts of watershed interventions through the analysis of land use/land cover changes, Land Surface Temperature variations, and crop monitoring using satellite imagery and mobile GPS tools. He is also actively involved in applying geospatial techniques to support various components of Climate Change Adaptation (CCA).

Analysis of Land Surface Temperature in Semi-Arid Maharashtra and Telangana: 2001–2020

Vijay Solanky and Ajit Jadhav

Executive Summary

The report, *"Analysis of Land Surface Temperature in Semi-Arid Maharashtra and Telangana: 2001–2020,"* presents an in-depth study of how Land Surface Temperature (LST) has evolved over two decades in Jalna district (Maharashtra) and Narayanpet district (Telangana). It highlights the growing importance of LST as a key indicator for understanding climate change, urban heat island effect, agricultural productivity, and hydrological cycles in semi-arid regions.

Why does Land Surface Temperature Matter?

LST acts as a vital 'thermometer' for the health of ecosystems and communities. Shifts in LST impact crop yields, water availability, and even local weather patterns, making it crucial for both policymakers and farmers to monitor and respond to these changes.

Reserch Methodology and Data Sources

The study leverages advanced satellite remote sensing data—primarily from MODIS imagery—paired with gridded rainfall datasets. Through a combination of rigorous data preprocessing, classification, and analysis, detailed day and night LST maps were generated. These maps capture seasonal, annual, and long-term temperature trends across both districts, revealing significant correlations between LST patterns and land use land cover (LULC) interventions.

Key Findings

Impact of Land Use Changes

Agricultural expansion, deforestation, and reforestation efforts were found to significantly influence local temperature patterns. Agricultural intensification often led to an increase in LST, while reforestation and conservation efforts contributed to cooling the landscape.

Watershed Development and Cooling Effect

Watershed development interventions—such as afforestation, soil conservation, and water harvesting—helped lower land surface temperatures locally, improving microclimates and supporting agricultural resilience.

Urban Heat Islands

Emerging urban centers in these districts show a distinct warming trend compared to surrounding rural areas, underscoring the need for climate-smart urban planning.

Conclusion

The study reinforces that land management practices play a pivotal role in shaping local temperature dynamics and climate resilience. Incorporating Land Surface Temperature (LST) monitoring into environmental planning, rural development, and climate adaptation efforts can enable more informed and effective interventions. By linking satellite-based insights with on-ground realities, this research offers a valuable foundation for designing sustainable, climate-responsive strategies across India's semi-arid regions and beyond. The findings highlight the importance of continuous, data-driven monitoring to navigate the evolving challenges of climate change.

Introduction

Land surface temperature (LST) is a key parameter in studying the thermal behaviour of the Earth's surface and has significant implications for climate, ecology, and human activities (Li et al., 2013; Shiff et al., 2021). Monitoring and analysing LST patterns at a local scale is crucial for understanding the spatio-temporal variations and their underlying factors. In the case of Jalna District, located in Maharashtra, India, studying the LST dynamics holds particular relevance due to its diverse land cover, urbanization trends, and potential impacts on local ecosystems and human well-being.

The spatio-temporal analysis of LST in Jalna and Narayanpet districts present an opportunity to investigate the interplay between natural and anthropogenic factors that influence land surface temperature. A study of LST trends over time will provide valuable insights into regional heat patterns, temperature anomalies and their drivers. This knowledge and understanding would be essential for assessing the impact of land-use changes, urban growth, vegetation variations, and climatic shifts on the area's temperature.

Previous studies have demonstrated the importance of spatio-temporal analysis of LST for understanding environmental processes and their consequences. For instance, Liu et al. (2017) conducted a similar study in a neighbouring region, examining the spatio-temporal variations of LST in the context of land use/land cover changes. Their findings revealed a significant relationship between land cover transitions and LST patterns, highlighting the potential for LST analysis to inform land management and urban planning decisions. Additionally, Patel and Patel (2019) explored the effects of climate change on LST in different districts of Maharashtra, providing regiona insights into the temperature dynamics and potential climate vulnerabilities.

Remote sensing data has emerged as a promising solution to overcome the limitations of interpolation techniques in mountainous areas and the sparsity of weather station coverage. The successful launch of Moderate Resolution Imaging Spectroradiometer (MODIS) on board TERRA (December 1999) and AQUA (May 2002) satellites has sparked significant interest among researchers in exploring new satellite-based methods. This emerging field has gained significant traction in recent years, offering innovative approaches to address the challenges associated with traditional interpolation techniques in mountainous regions. By capturing data at regular intervals and covering large spatial extents, satellite-based methods offer a unique advantage in characterizing the spatio-temporal variability of weather variables in mountainous regions.

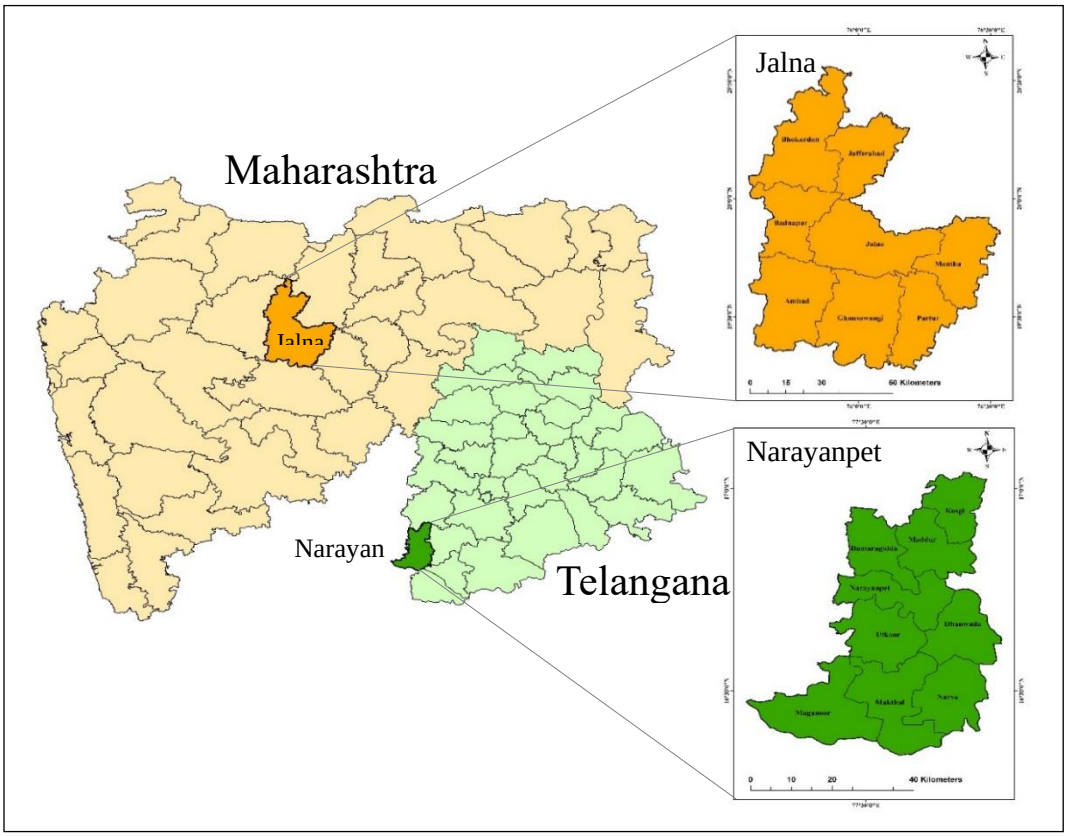
By conducting a comprehensive spatio-temporal analysis of LST in Jalna and Narayanpet districts, this study aims to contribute to the existing body of knowledge regarding the thermal characteristics of the area. The findings will have implications for climate resilience planning, urban development strategies, and ecosystem management in the district. Understanding the LST patterns and their underlying drivers can guide policymakers, land managers, and urban planners in making informed decisions to mitigate the adverse effects of temperature extremes and promote sustainable development.

Study area description:

Jalna District is located in the Marathwada region of central Maharashtra, India. The district covers an area of approximately 7,718 square kilometres and is bordered by Chhatrapati Sambhajinagar (previously known as Aurangabad) district to the north, Beed district to the east, Parbhani district to the southeast, and Buldhana district to the west. Geographically, Jalna district is characterized by its undulating terrain and a

mix of agricultural plains and hilly regions. The Godavari River flows along the district's northern boundary, providing irrigation water for agriculture. The rivers Dudhana, Gulati, and Purna serve as the main tributaries of the Godavari. The Purna sub-basin encompasses a significant portion of the district, contributing to its hydrological and ecological richness. The district has a tropical climate, with hot summers and relatively mild winters. The summer season, which lasts from March to June, is characterized by high temperatures, often exceeding 40 degrees Celsius (104 degrees Fahrenheit). The monsoon season arrives in June and lasts until September, bringing moderate to heavy rainfall.

Narayanpet district, located in Telangana, consists of its nine administrative blocks that cover a geographical area of 2,369 sq km. Nestled on the banks of the Krishna River, the district enjoys a strategic location that supports both agriculture and local livelihoods. The region experiences moderate rainfall between 600 to 800 mm, which sustains its agrarian economy, although the summers can be particularly challenging with temperatures frequently exceeding 38°C. This unique blend of geographical features and climatic conditions shapes the district's development trajectory and underscores the importance of adaptive strategies for water management and sustainable growth.



Map 1: Location map of Jalna and Narayanpet districts.

Main Objectives of the Study:

- Understand the temporal trends in Land Surface Temperature (LST) over a 20-year period (2001 – 2020)

  By examining these trends, researchers can identify periods of significant warming or cooling, assess the impact of climatic factors, and correlate these changes with land use patterns, such as urban expansion or shifts in vegetation cover. Ultimately, this objective not only helps to reveal the

long-term effects of climate change and anthropogenic activities on surface temperatures but also provides essential insights for developing targeted strategies for environmental management and sustainable development.

- Evaluate the impact of Land Use Land Cover (LULC) change on LST

  Land Use Land Cover (LULC)—such as urban expansion, agricultural intensification, deforestation, or afforestation—directly influences the LST. By analysing historical LULC data alongside LST trends, the study aims to pinpoint specific interventions that have led to noticeable thermal variations. The goal is to understand the thermal impact of converting vegetated or natural landscapes into built-up or agricultural areas and to evaluate mitigation strategies, such as reforestation or the development of green spaces. This evaluation highlights the relationship between human-induced land cover changes and surface temperature dynamics. It informs the development of sustainable land management practices to minimise environmental adverse thermal effects.

Methodology:

A. Data Collection:

- MODIS LST (Z. Wan et al., 2021) satellite imagery data for 20 years was obtained from Google Earth Engine, covering a significant duration to capture yearly variations in the Jalna district's day and night land surface temperatures.
- Gridded rainfall data for 20 years was downloaded from the IMD website.

- Data Preprocessing:
- The area of interest was clipped and projected from Minu Sinusoidal to the Geographic Coordinate System (GCS) to maintain the original extent of the study area.

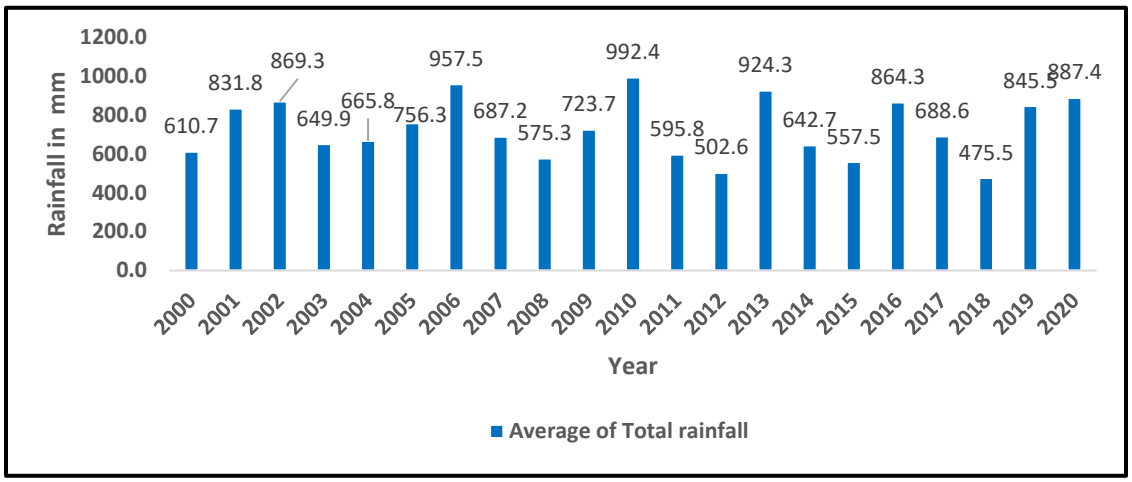
- Land Surface Temperature Calculation:
- The MODIS LST data was classified using a fixed interval approach to calculate the LST for 20 years in the Jalna and Narayanpet districts. This classification allows for clear visualisation and analysis of the variation in day LST across the district throughout the 20 years for summer months.
- To better understand LST variations in Jalna and Narayanpet, daytime LST maps were created for the summer season over 20 years. These maps visually depict the spatial distribution and temporal changes in land surface temperature across different district regions.
- For the village-level LST analysis, 30-meter resolution satellite imagery from Landsat-5 and Landsat-8 was utilised.

Result and Discussion

The district experiences a dry and tropical climate characterised by very hot summers, mild winters, and a humid southwest monsoon season with moderate rainfall. The district has three main seasons: a hot to warm, humid monsoon season from June to September, an incredibly dry winter season from October to February, and a hot, dry summer season from March to June. During the monsoon season, temperatures range from 21°C to 30°C, while in winter, they drop significantly between 10°C and 25 °C. Night temperatures range from 20°C to 25°C, often accompanied by a cool breeze. The district has two distinct rainfall regions: Bhokardan, Jafrabad, and Jalna talukas receive around 700 mm of rainfall, favouring *kharif* crops, whereas Ambad and Partur talukas receive about 800 mm, more suitable for *rabi* crops. Overall, the average annual rainfall in the district is 725.80 mm, with about 83% occurring between June and September, making July the wettest month.

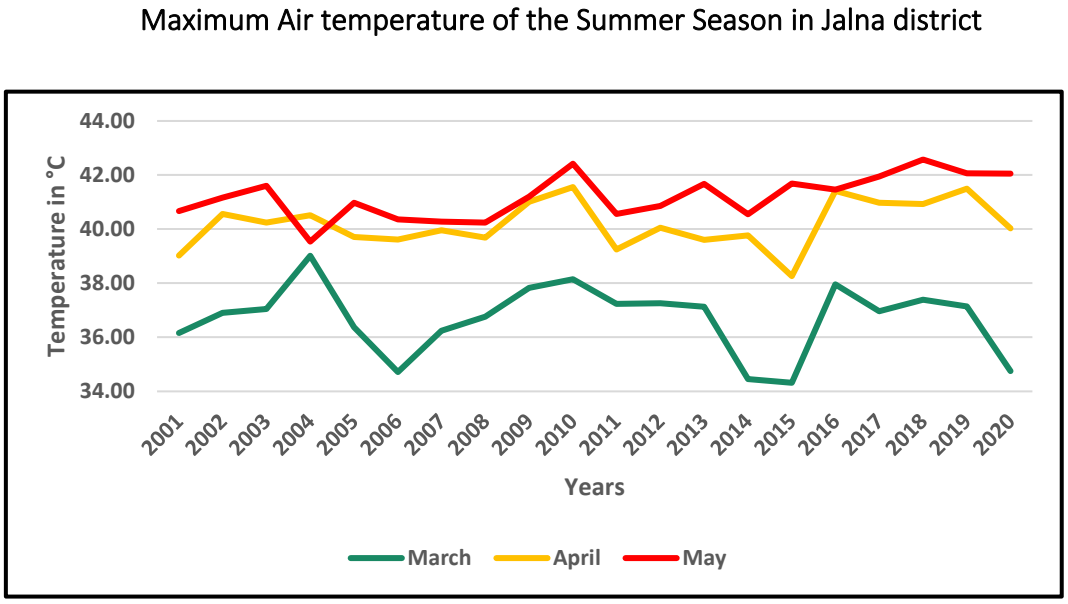
Humidity levels in the district remain high during the monsoon season but drop significantly in the summer months, with relative humidity between 20% and 25% in the afternoons. Winds are generally light to moderate, with increased speed during the latter half of the hot season and throughout the monsoon. During summer, winds predominantly blow from the west and north, while during the southwest monsoon season, they shift to directions between southwest and northwest.

Jalna district average of total annual rainfall



Graph-1: Jalna district average of total annual rainfall

Graph-1 illustrates the annual rainfall trends in the Jalna district from 2000 to 2020, showing fluctuations in precipitation levels. The rainfall generally varied between 500 mm and 1000 mm, with certain years experiencing significantly higher rainfall than others. Notably, 2002, 2006, 2010, 2014, and 2020 recorded higher rainfall, with values exceeding 800 mm, indicating wetter periods. In contrast, years such as 2004, 2008, 2011, and 2018 saw comparatively lower rainfall, highlighting periods of reduced precipitation. The highest recorded rainfall in the given timeframe was in 2020, reaching 887.4 mm, suggesting an increase compared to the previous years. The data suggests that rainfall in Jalna district does not follow a consistent increasing or decreasing trend but exhibits fluctuations, with alternating dry and wet years. Climatic changes, monsoon patterns, or other regional environmental factors could influence these variations. Despite these inconsistencies, the overall rainfall pattern suggests that the district experiences periodic fluctuations rather than a long-term significant rise or decline in rainfall levels.

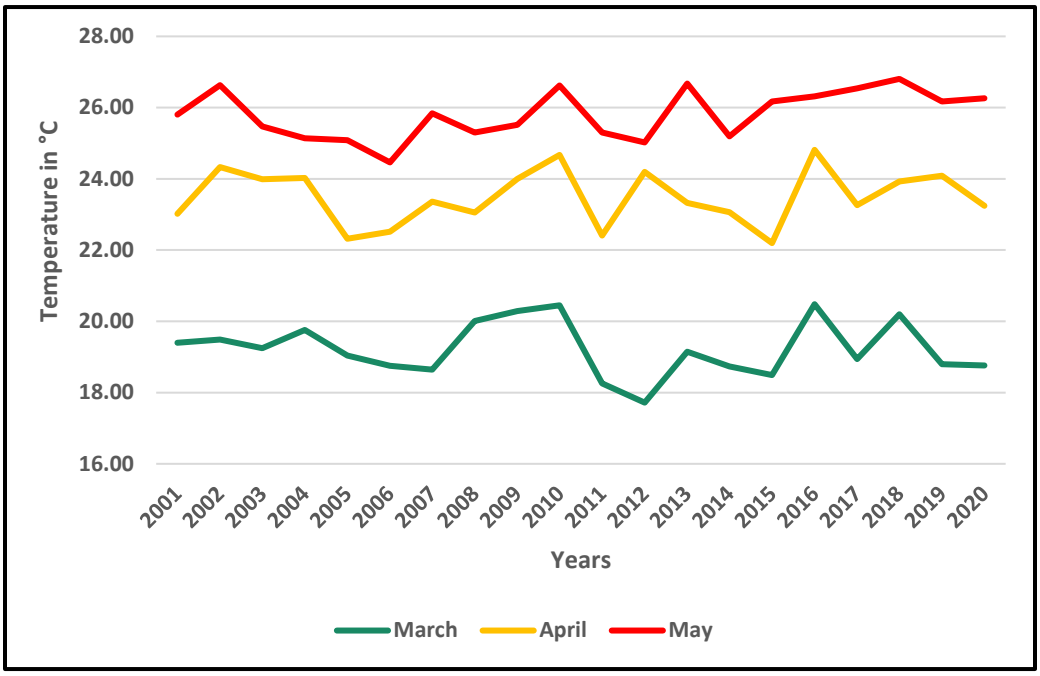


Graph 2: Maximum Air temperature of the Jalna district

Graph-2 illustrates the temperature trends for March, April, and May from 2001 to 2020, showing how temperatures have fluctuated over the years. May consistently records the highest temperatures, ranging between 40°C and 43°C. There is a slight increasing trend in May's temperatures, suggesting the month is progressively hotter. April follows closely, with temperatures between 39°C and 42°C, showing moderate fluctuations but maintaining relatively stable conditions. Conversely, March records the lowest temperatures among the three months, fluctuating between 35°C and 39°C. Unlike May and April, March exhibits more noticeable variations in temperature, with occasional drops and rises.

Over the years, the general trend indicates that temperatures in all three months remain pretty high, highlighting warm to extreme heat conditions. The increasing trend in May temperatures suggests a gradual rise in summer heat levels, which could be attributed to climate change or other environmental factors. April also exhibits a stable but warm temperature range, maintaining its position as the second-warmest month in the given period. While the coolest of the three, March, still experiences high temperatures, indicating that heat levels start rising early in the season.

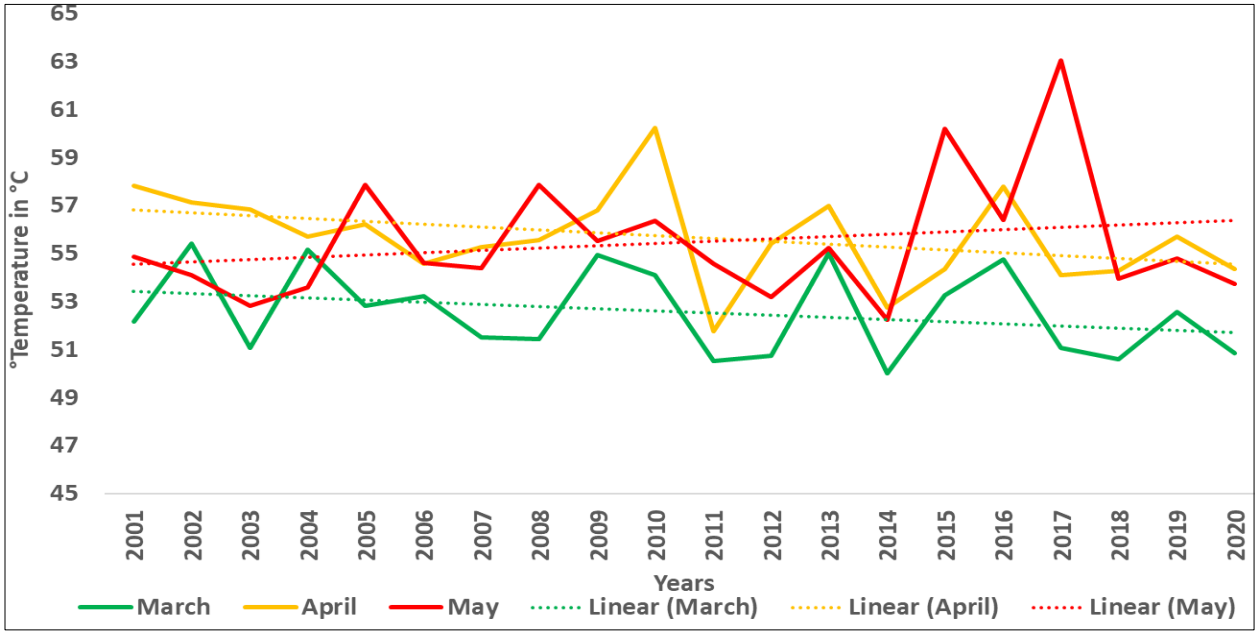
Overall, the graph suggests that the summer months are experiencing consistently high temperatures, with slight increases in May. This could have implications for agriculture, water supply, and general living conditions, making monitoring and addressing rising temperatures in the coming years essential.



Graph 3: Minimum Air temperature of the Jalna district

Graph-3 illustrates the minimum temperatures recorded in Jalna during March, April and May from 2001 to 2020. It demonstrates that May consistently had the highest minimum temperatures, generally between 25°C and 27°C, with a slight increasing trend over the years. This suggests that nights in May have been warming over time. April followed, with minimum temperatures fluctuating between 22°C and 25°C, showing some variations but no clear long-term trend, implying relatively stable weather patterns for this month. March experienced the lowest minimum temperatures, typically between 18°C and 21°C, with noticeable year-to-year fluctuations but no firm indication of significant change. While the overall temperature patterns seem stable, occasional spikes and dips may be attributed to seasonal or climatic variations. The temperature fluctuations for all three months indicate the influence of natural climate variations or external factors, but there is no drastic shift in long-term minimum temperature trends. The data suggest that while some months display a gradual warming trend, the overall minimum temperatures in Jalna have remained relatively consistent over the past two decades, with minor variations occurring periodically.

Day Maximum Land Surface Temprature of Jalna District



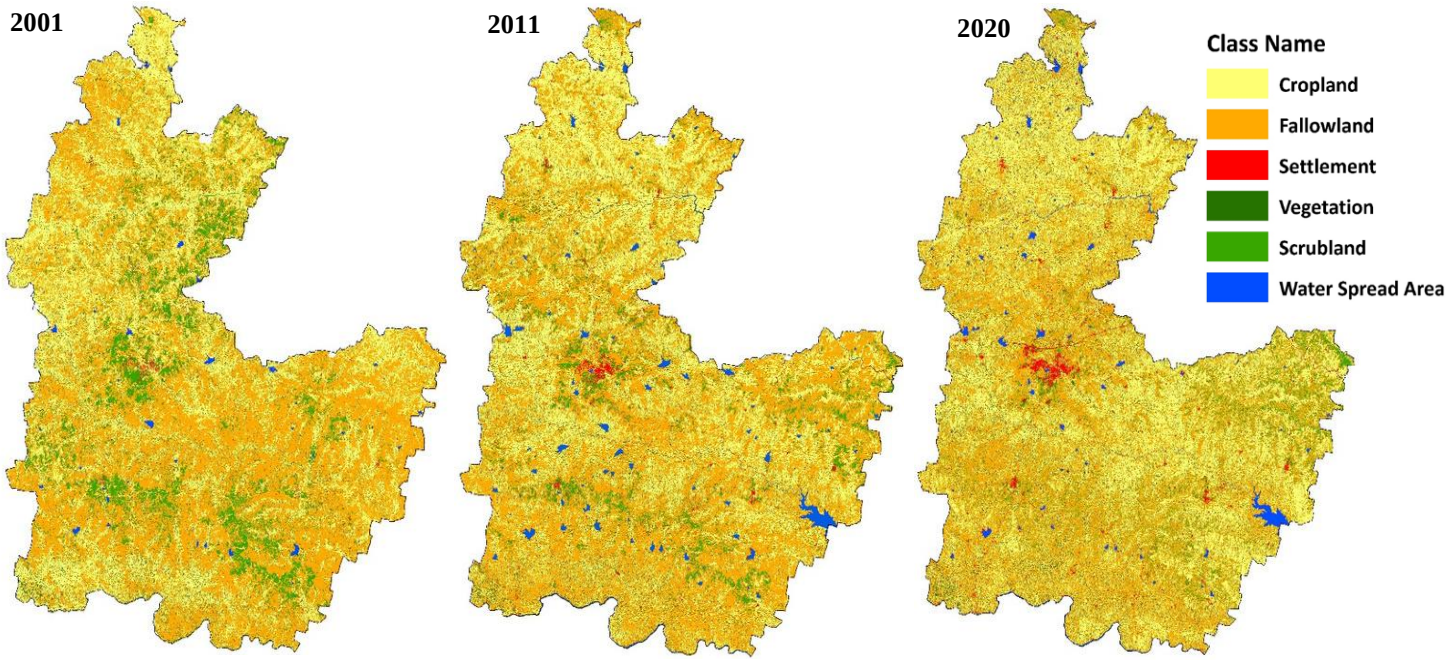
Graph 4 Day Maximum Land Surface Temperature of Jalna District

The graph illustrates the temperature trends in Jalna for March, April, and May from 2001 to 2020. The temperature trends reveal a slight decline for March and April, while May exhibits an increasing trend. Notably, a significant spike in May temperatures is observed post-2014, suggesting a shift towards more extreme heat events in the later years. When comparing the temperature records across the two decades, April has recorded higher temperatures than May for 10 years, whereas May has surpassed April in only 5 years. This pattern highlights variations in seasonal temperature dynamics, with May showing a more pronounced warming trend. The linear trend lines confirm this trajectory, with May's temperature steadily increasing over the years, which may indicate climate change influences or shifting weather patterns.

Land Use Land Cover Changes:

LST and LULC are distinctly evident in how land cover changes directly affect an area's thermal characteristics. The research shows that areas undergoing rapid urbanisation or conversion of natural landscapes into cropland and settlements tend to exhibit higher LST values. This is primarily due to reduced vegetation cover and replacing natural surfaces with materials with lower albedo and higher heat retention capacity, increasing surface temperatures. Conversely, regions with abundant vegetation, such as forests or areas with significant water bodies, generally show lower LST owing to enhanced evapotranspiration and better moisture retention. These contrasting thermal patterns underline the critical impact of LULC dynamics on regional climate, emphasising the need for sustainable land management practices to mitigate adverse temperature rises.

Land Use Land Cover Classification of Jalna District (*Rabi* Season)



Map 2: Land Use and Land Cover Classification of Jalna 2001, 2010,2020

Class name	Area in Hectare		
	2001	2010	2020
Cropland	2,71,625.3	2,92,073.4	3,73,821.6
Fallow land	4,13,083.2	3,99,681.7	3,42,235.9
Vegetation	10,189.8	14,861.3	16,673.1
Settlement	8,129.8	8,578.4	11,986.3
Scrubland	59,518.9	38,607.3	16,835.8
Waterbody	7,186.1	15,930.9	8,180.4

Table-1 Statistic of Land Use and Land Cover Classification of Jalna 2001, 2010,2020

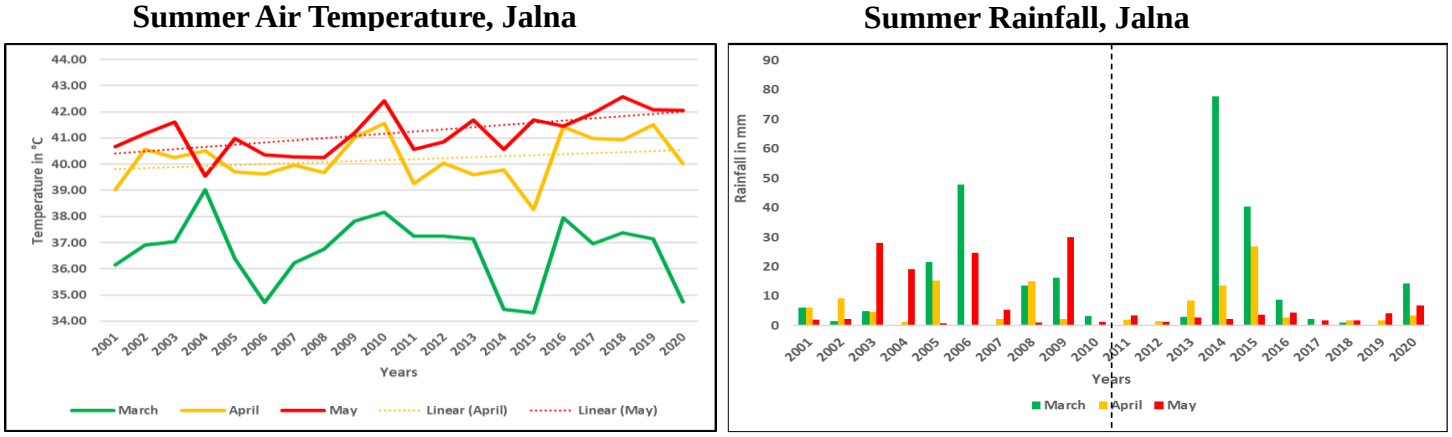
The comparative analysis of the LULC maps for Jalna from 2001, 2010, and 2020 shows a significant transformation in land use patterns over the years. One of the most evident changes is the steady expansion of cropland. Over the two decades, agricultural land has increased, indicating a shift toward intensified farming and land utilization for crop production. This expansion has largely come at the expense of fallow land, which has been consistently declining as more land is brought under cultivation.

Another major change is the noticeable increase in settlement areas. Between 2001 and 2020, urban and rural settlements have expanded, reflecting population growth, infrastructural development, and economic activities. This expansion has contributed to the reduction of other land types, particularly fallow land and scrubland. The reduction in scrubland is a significant trend, as it has been decreasing rapidly over the years, suggesting that previously uncultivated and barren land is being converted for either agriculture or urban development.

Vegetation cover has shown a gradual increase from 2001 to 2020, which could be attributed to afforestation efforts, conservation initiatives, or natural regeneration. While this is a positive change, it is relatively minor compared to the large-scale conversion of land for agriculture and settlements. On the other hand, water bodies have fluctuated over the years. There was an increase in water-covered areas between 2001 and 2010, but a decline was observed in 2020, indicating possible changes in water availability, rainfall patterns, or management practices.

Overall, the LULC maps highlight a clear trend of increasing agricultural and settlement areas, leading to the decline of fallow land and scrubland. The growth in vegetation cover is a positive aspect, but the fluctuations in water bodies raise concerns about long-term water sustainability. These transformations reflect the dynamic nature of land use in Jalna, driven by agricultural expansion, urbanization, and environmental changes.

Jalna: Summer Temperature and Summer Rainfall



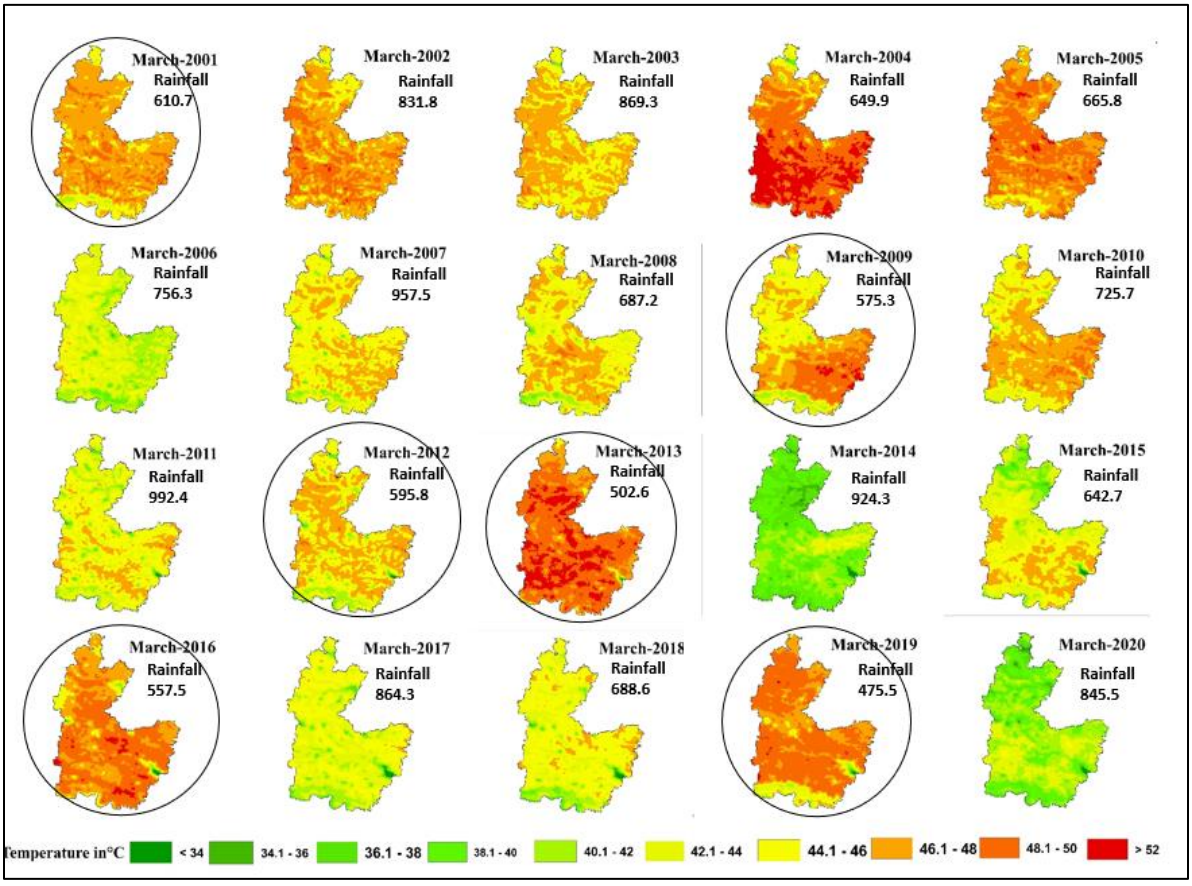
Graph 5: Summer air temperature and Summer Rainfall of the Jalna district.

The summer temperature trends in Jalna from 2001 to 2020 indicate a gradual rise, particularly in the months of April and May. During the first decade (2001–2010), March temperatures showed fluctuations,

peaking around 2004 before slightly declining. April and May remained relatively stable, but an increasing trend in May's temperature was noticeable. In the second decade (2011–2020), temperatures continued to rise, with May experiencing the highest temperatures. March temperatures fluctuated, with notable drops in 2015 and 2020. The linear trend lines for April and May confirm an overall warming pattern, suggesting that summer temperatures in Jalna are gradually increasing over the years.

Rainfall patterns in Jalna over these two decades have been highly irregular. Between 2001 and 2010, rainfall remained low, with occasional peaks in 2004, 2006, and 2008. March experienced significant rainfall in some years, while April and May had relatively lower precipitation. The second decade (2011–2020) showed even more extreme variations. Significant rainfall events occurred in 2014 and 2015, particularly in March and April, but most other years recorded minimal or no rainfall. This suggests a shift towards more unpredictable rainfall patterns, with occasional heavy precipitation but an overall decline in summer rainfall.

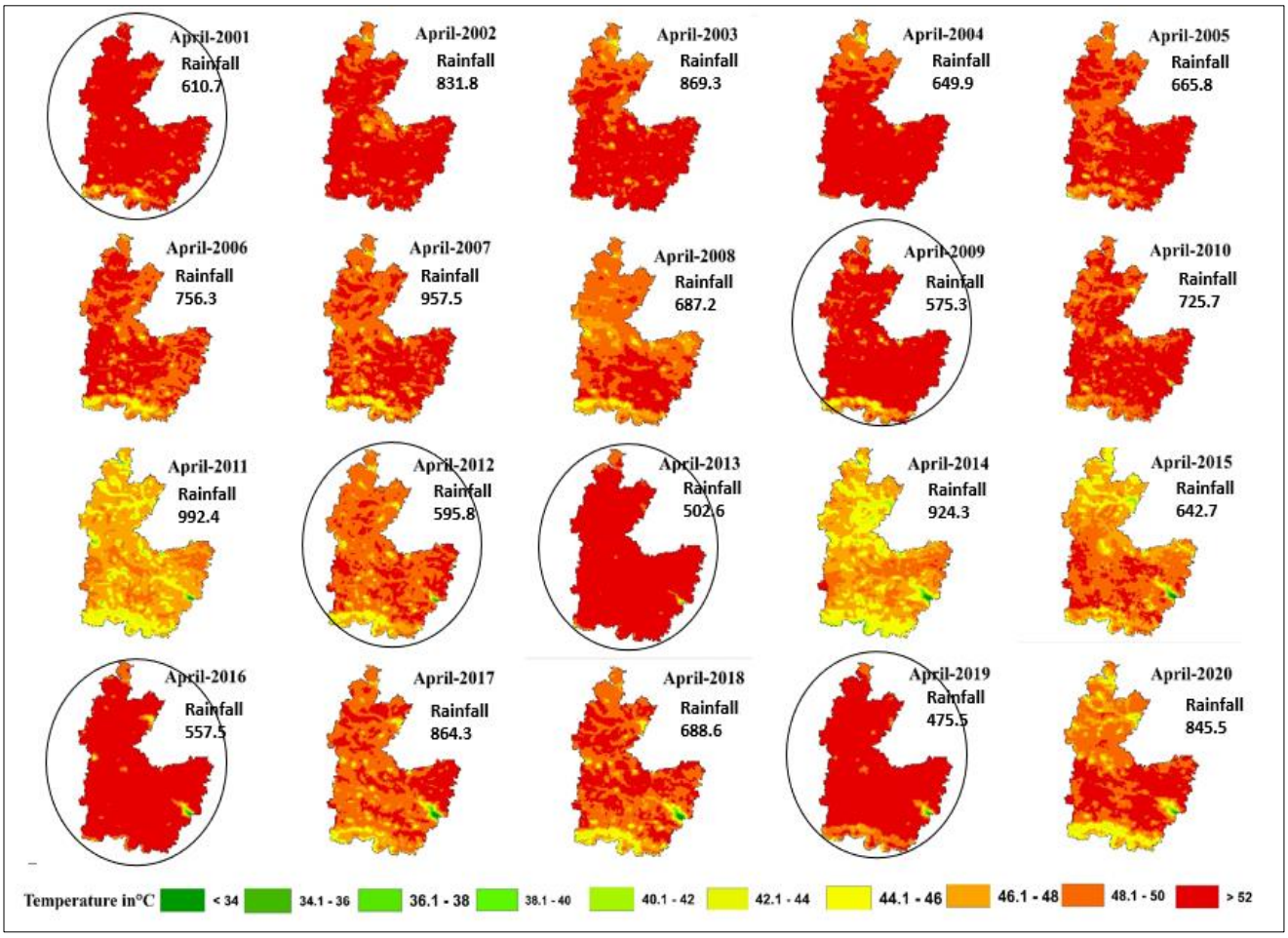
Overall, the climate trends in Jalna indicate rising summer temperatures and erratic rainfall patterns. The increasing heat, particularly in April and May, along with inconsistent rainfall, could have significant implications for agriculture, water availability, and overall climate conditions in the region. The observed changes suggest the impact of climate variability, emphasising the need for adaptive measures in water resource management and agricultural planning.



Map 3: Land Surface Temperature of Jalna 2001-2020 of March

The LST patterns in Jalna from March 2001 to 2020 reveal a strong correlation between temperature variations and rainfall distribution. The years marked by drought conditions, specifically 2004, 2013, 2016, and 2019, exhibit notably higher land surface temperatures, as seen in the circled maps. These years experienced insufficient rainfall, leading to increased heat retention in the land surface. In contrast, years with substantial rainfall, such as 2006, 2009, 2014, and 2015, demonstrated lower land surface temperatures due to increased soil moisture and vegetation cover, which helped regulate surface heating. The spatial distribution of rainfall also played a crucial role in determining temperature variations. In some years, even if total rainfall was moderate, uneven distribution within the month resulted in temperature fluctuations. Areas with minimal precipitation exhibited elevated temperatures, while regions receiving higher rainfall experienced relatively cooler conditions. The overall trend indicates that a lack of precipitation exacerbates land surface warming, whereas adequate and well-distributed rainfall acts as a mitigating factor against rising temperatures. These observations emphasize the critical role of rainfall patterns in influencing surface temperatures and highlight the susceptibility of Jalna's climate to drought-induced heating.

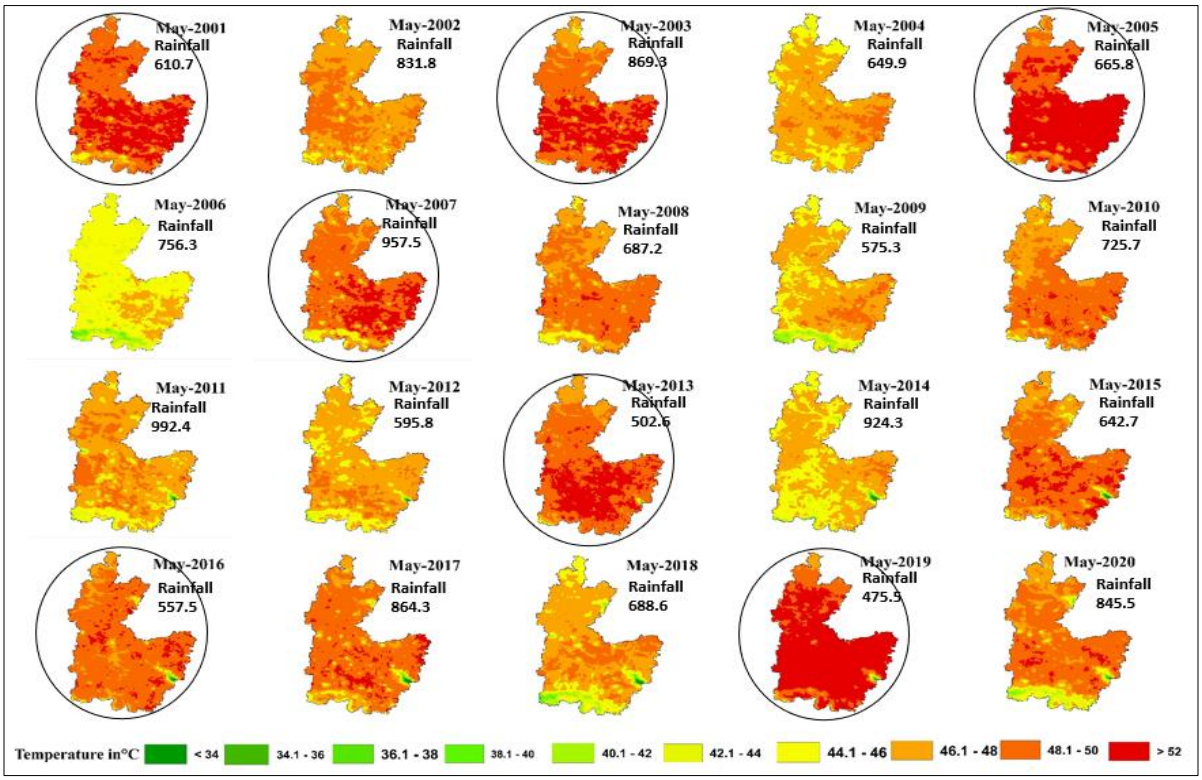
Jalna: Land Surface Temperature in April, against the Annual & April Rainfall



Map 4: Land Surface Temperature of Jalna 2001-2020 of April

The image illustrates the LST patterns in Jalna from April 2001 to April 2020. The color gradient represents temperature variations, with dark red indicating extreme heat exceeding 50°C and green showing relatively lower temperatures. Drought years, which are circled, exhibit significantly higher land surface temperatures, correlating with low rainfall in those years, such as June 2003 to May 2004, June 2013 to May 2014 and June 2018 to May 2019. These years show an extensive presence of dark red shades, indicating extreme temperatures across large portions of the region. Conversely, years with relatively higher rainfall, such as 2006, 2009, 2014, and 2015, display more yellow and green areas, signifying comparatively lower temperatures. This suggests that rainfall is crucial in moderating surface temperature by providing moisture and reducing heat intensity. The spatial distribution of heat varies yearly, indicating that while some regions consistently experience high temperatures, others witness fluctuations. The comparison of temperature trends over the years reveals that April generally experiences extreme heat, but temperatures tend to be lower in May. This pattern indicates a potential shift in atmospheric and climatic conditions between these months. The correlation between rainfall and LST highlights the importance of precipitation in mitigating extreme heat effects, with inadequate rainfall leading to intensified warming and severe drought conditions.

Jalna: Land Surface Temperature in May, against the Annual & May Rainfall

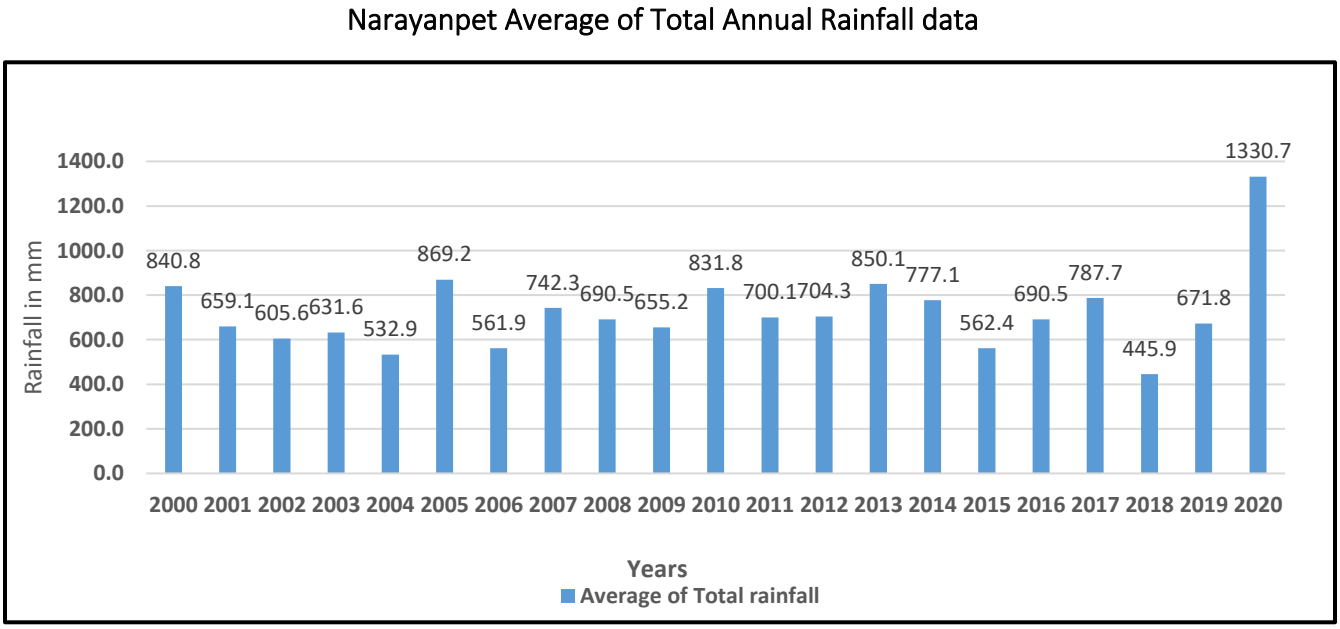


Map 5: Land Surface Temperature of Jalna 2001-2020 of May

The image illustrates the LST variations in Jalna for May from 2001 to 2020, highlighting how extreme heat is distributed across different years. In some years, particularly those with lower rainfall, widespread red areas dominate the map, indicating temperatures exceeding 50°C. Drought years such as 2001, 2005, 2007, 2013, 2016, and 2019 show intense heat, with large portions of the region covered in dark red, signifying extreme surface temperatures. The spatial distribution of heat is not uniform, as some years exhibit concentrated hot zones while others show a more scattered pattern. However, when compared to April, the overall land surface temperature in May appears to be slightly lower, suggesting a seasonal cooling trend. This could be attributed to factors such as increased cloud cover, occasional pre-monsoon showers, and changes in atmospheric circulation, which help regulate surface temperatures. Rainfall plays a crucial role in mitigating extreme heat, as observed in years like 2006, 2009, 2011, 2014, and 2015, where higher rainfall resulted in lower surface temperatures, with more yellow and green areas on the map. This highlights the strong correlation between precipitation levels and land temperature, where years with sufficient rainfall experience milder temperatures, while drought-affected years suffer from extreme heat stress. The data provides valuable insights into the impact of climatic variations on temperature patterns in Jalna, emphasizing the importance of rainfall in controlling extreme heat events.

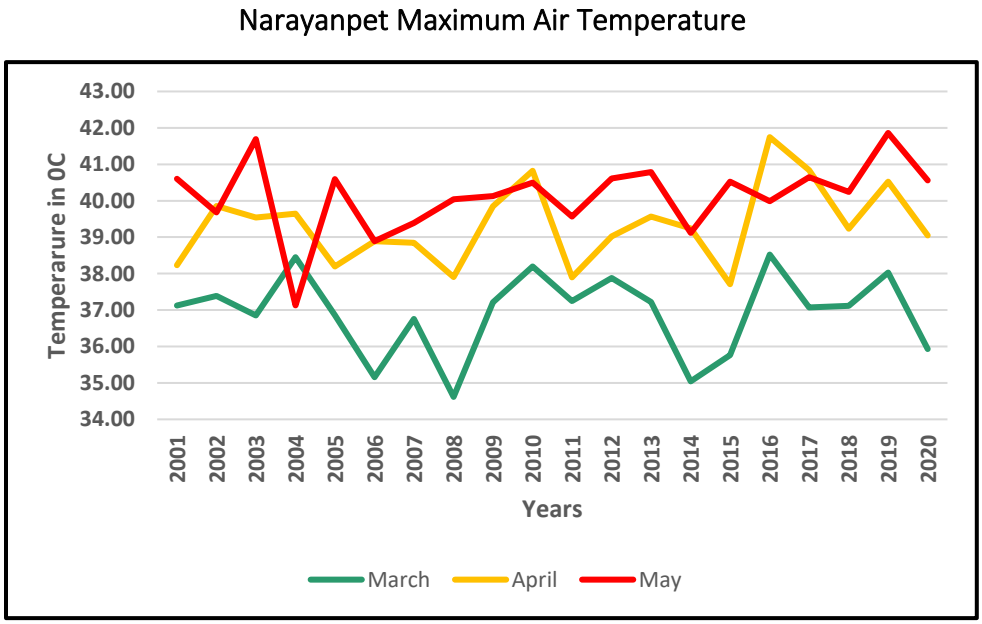
NARAYANPET

Narayanpet district in Telangana, India, has a tropical climate with pronounced wet and dry seasons. Temperatures typically fluctuate between 16.7°C and 38.9°C, rarely falling below 12.8°C or surpassing 42.2°C. The wet season, lasting from June to September, brings heavy rainfall, high humidity, and predominantly overcast skies. July and August are the peak monsoon months, contributing the bulk of annual precipitation. From October to May, the dry season prevails, marked by clear skies, minimal rainfall, and lower humidity. The hottest period occurs in April and May, with average highs soaring to 42°C. Understanding Narayanpet climate, seasonal rainfall variability, temperature extremes, and humidity patterns is critical for agricultural productivity, infrastructure planning, and adapting daily activities to weather conditions. This knowledge ensures resilience in the face of the region's climatic challenges.



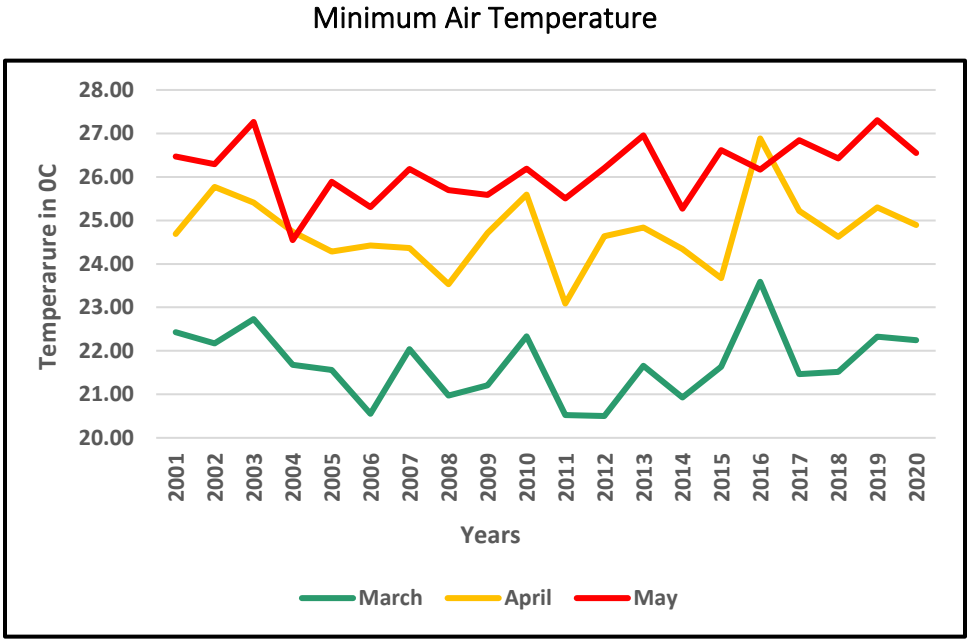
Graph 6: Narayanpet district average of total annual rainfall

The graph represents the annual rainfall trends in the Narayanpet district from 2000 to 2020, showing fluctuations in precipitation over the years. Most years received rainfall between 500 mm and 900 mm, with variations observed across different periods. Some years, such as 2005, 2010, 2013, and 2014, recorded higher rainfall, exceeding 800 mm, while years like 2004, 2006, 2015, and 2018 saw relatively lower rainfall, indicating periods of reduced precipitation. A striking feature of the graph is the exceptionally high rainfall in 2020, which surpassed 1400 mm, making it the highest recorded rainfall in the given period. This sharp increase in 2020 stands out compared to previous years, suggesting an unusual spike in precipitation. Overall, the rainfall pattern in the Narayanpet district does not show a consistent increasing or decreasing trend but exhibits irregular fluctuations with alternating wet and dry years. These variations could be attributed to changes in monsoon patterns, climate fluctuations, or environmental factors affecting the region. While most years experienced moderate rainfall, the extreme peak in 2020 highlights the unpredictable nature of rainfall in the district.



Graph 7:Maximum Air temperature of Narayanpet district

The graph represents the air temperature trends in Narayanpet district for March, April, and May from 2001 to 2020. Over the years, temperatures have fluctuated, with the highest temperatures consistently recorded in May, followed by April and then March. The temperature in May has mostly remained above 39°C, with some years exceeding 41°C, particularly in recent years, indicating a rising trend. April temperatures have also fluctuated but generally stayed between 38°C and 41°C, showing periodic spikes, such as in 2010 and 2017. March temperatures, on the other hand, have shown more variation, with some years recording a significant drop below 36°C, particularly in the mid-2000s, but an overall increasing pattern is observed after 2010. The data suggests that the summer months in Narayanpet are getting progressively hotter, with May consistently experiencing the highest temperatures. Climate variability, heatwaves, and changing weather patterns could be contributing factors to these temperature trends. The overall pattern indicates an increasing temperature trend, especially in April and May, suggesting that the district is experiencing warming conditions over time.

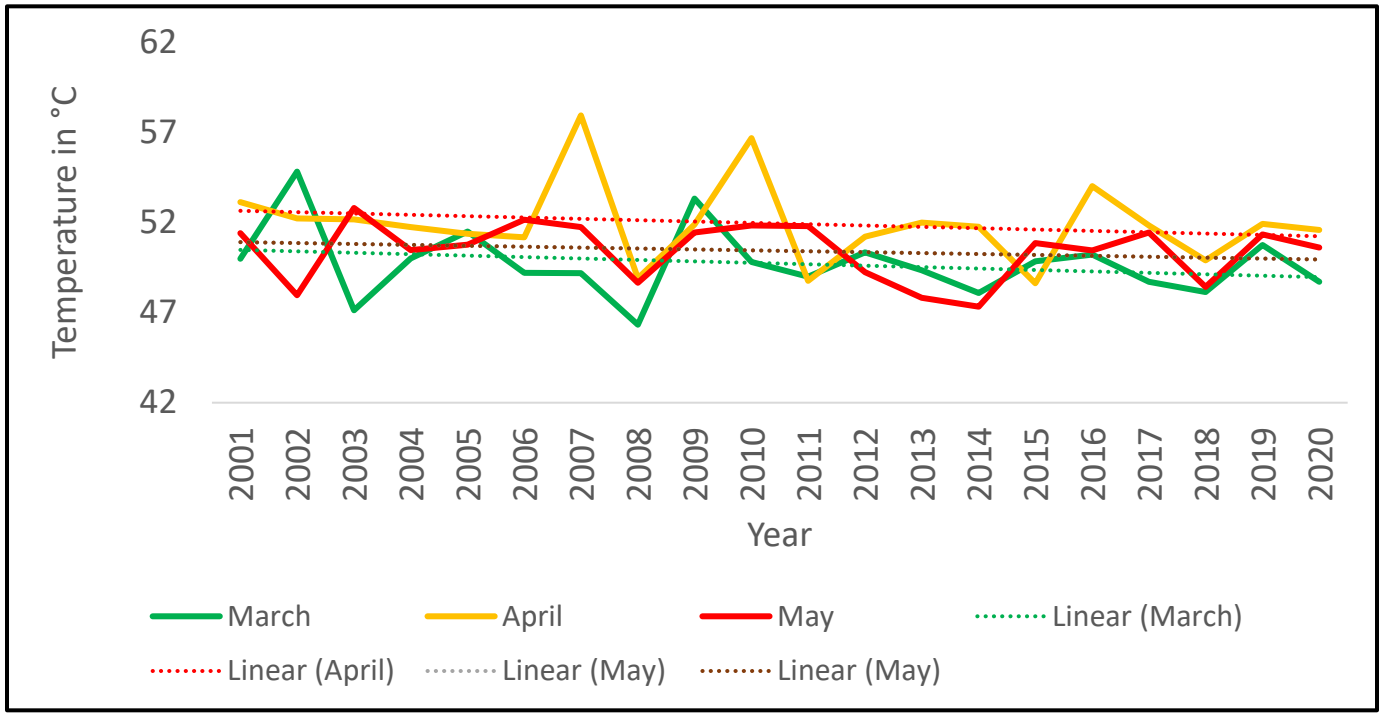


Graph 8: Minimum Air temperature of Narayanpet district

The graph displays the minimum air temperature in the Narayanpet district for the same period and months. Unlike the maximum temperature graph, this one shows relatively stable variations but still presents a gradual upward trend. The red line (May) again records the highest temperatures, fluctuating between 25°C and 27°C, followed by April (yellow) and March (green), which show lower temperatures. March exhibits the lowest minimum temperatures, mostly ranging between 20°C and 23°C. Although fluctuations are present, the overall trend suggests that nighttime and early morning temperatures are gradually increasing over the years. This rise in minimum temperatures indicates that the district is experiencing warmer nights, which could impact local climate patterns, agriculture, and water retention in the region.

Both graphs highlight a general warming trend in the Narayanpet district, with both maximum and minimum temperatures increasing over the years. This suggests that the region is experiencing hotter days and warmer nights, which could have significant implications for the environment, water availability, and overall living conditions.

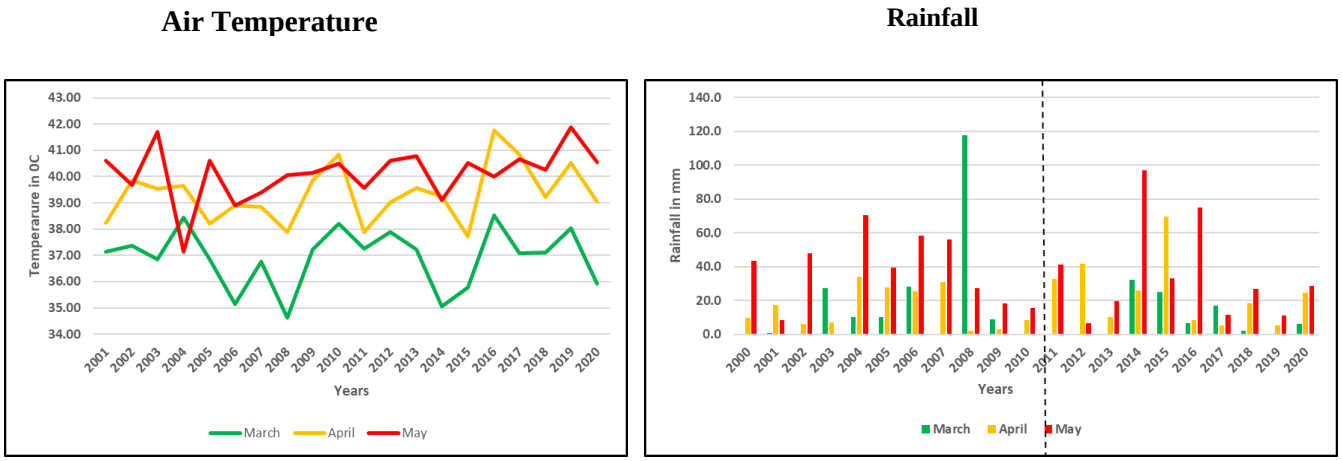
Narayanpet: Average Summer Day Maximum Land Surface Temperature



Graph 9 Day Maximum Land Surface Temperature of Narayanpet District

The graph represents the LST trends for Narayanpet from 2001 to 2020 during March, April, and May. The data exhibits noticeable fluctuations, with April consistently recording the highest temperatures, marked by multiple peaks. The trend lines indicate a gradual increase in April temperatures, while March and May temperatures remain relatively stable. Significant variations are observed across different years, with extreme highs and lows suggesting potential climatic changes or anomalies affecting the region. These trends highlight the impact of rising temperatures, especially in the peak summer months, which could have implications for agriculture, water availability, and overall climate conditions in Narayanpet.

Narayanpet: Summer Temperature and Summer Rainfall



Graph 5: Summer air temperature and Summer Rainfall of the Narayanpet district.

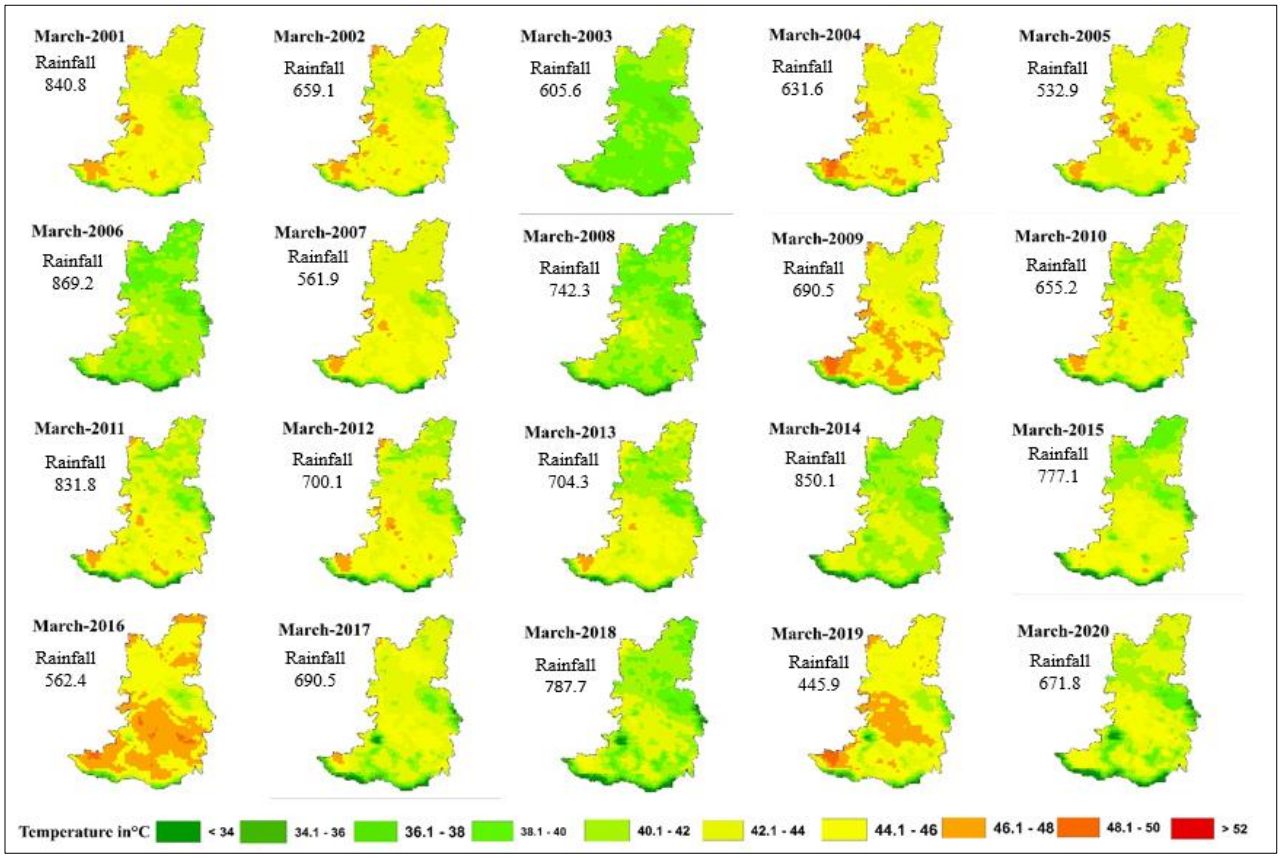
The provided maps and graphs illustrate the climatic trends in Narayanpet, explicitly focusing on temperature and rainfall variations from 2001 to 2020. The temperature graph highlights a noticeable upward trend, especially during May, which has consistently recorded the highest temperatures, exceeding 41°C in recent years. April also exhibits a gradual increase in temperature over time, though with some fluctuations. While remaining the coolest of the three months, March shows variations in temperature trends, indicating an overall warming pattern.

On the other hand, the rainfall graph reveals high precipitation variability during March, April, and May over the years. May generally experiences the highest rainfall compared to the other months, but there are significant year-to-year fluctuations. Some years record substantial rainfall spikes, while others show minimal precipitation, suggesting an unpredictable monsoon pattern.

The observed increase in temperature and erratic rainfall trends highlight potential climatic changes in Narayanpet, possibly influenced by factors such as deforestation, land-use changes, and global warming. The rising temperatures, especially during peak summer months, could have severe implications for agriculture, water availability, and overall livelihood sustainability in the region. The irregular rainfall patterns might further impact crop cycles and groundwater recharge, necessitating proactive water conservation measures and adaptive agricultural practices.

Overall, these climatic shifts emphasise the importance of watershed management, afforestation, and climate-resilient strategies to mitigate the adverse effects of rising temperatures and unpredictable rainfall in Narayanpet.

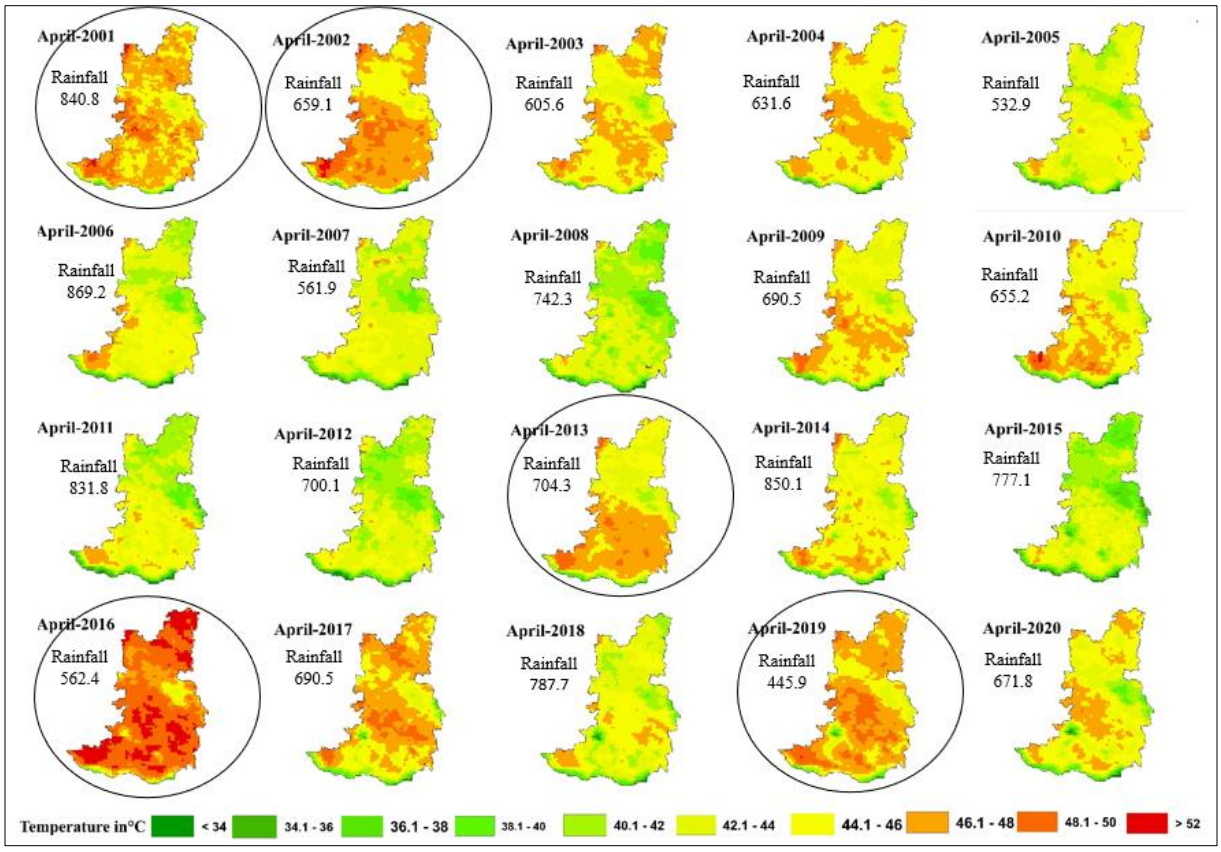
Narayanpet: Average Land Surface Temperature in March, against the Annual Rainfall



Map 6: Land Surface Temperature of Naraynpet 2001-2020 of March

This map is LST variations in Narayanpet for March from 2001 to 2020, showcasing clear temperature trends and their relationship with rainfall. Over the years, a distinct shift in temperature distribution can be observed, particularly in the southern and southwestern regions, where temperatures have progressively increased, as indicated by the transition from yellow and orange to deep red shades. This warming trend suggests a significant rise in LST, likely influenced by climate change and local environmental factors. The presence of green and yellow areas in earlier years represented moderate temperatures, but as time progresses, the frequency and intensity of warmer shades have increased, signaling an overall warming pattern. The correlation between temperature variations and monthly rainfall is also evident, as years with lower rainfall tend to show more widespread warmer zones, reinforcing the impact of precipitation levels on surface heating. The increase in extreme heat events in March is concerning, as it indicates a potential climate change-driven shift that could have consequences on agriculture, water resources, and the overall ecosystem of the district. This visualisation highlights the need for climate adaptation measures to mitigate the growing impact of rising temperatures on Narayanpet's environment and livelihoods.

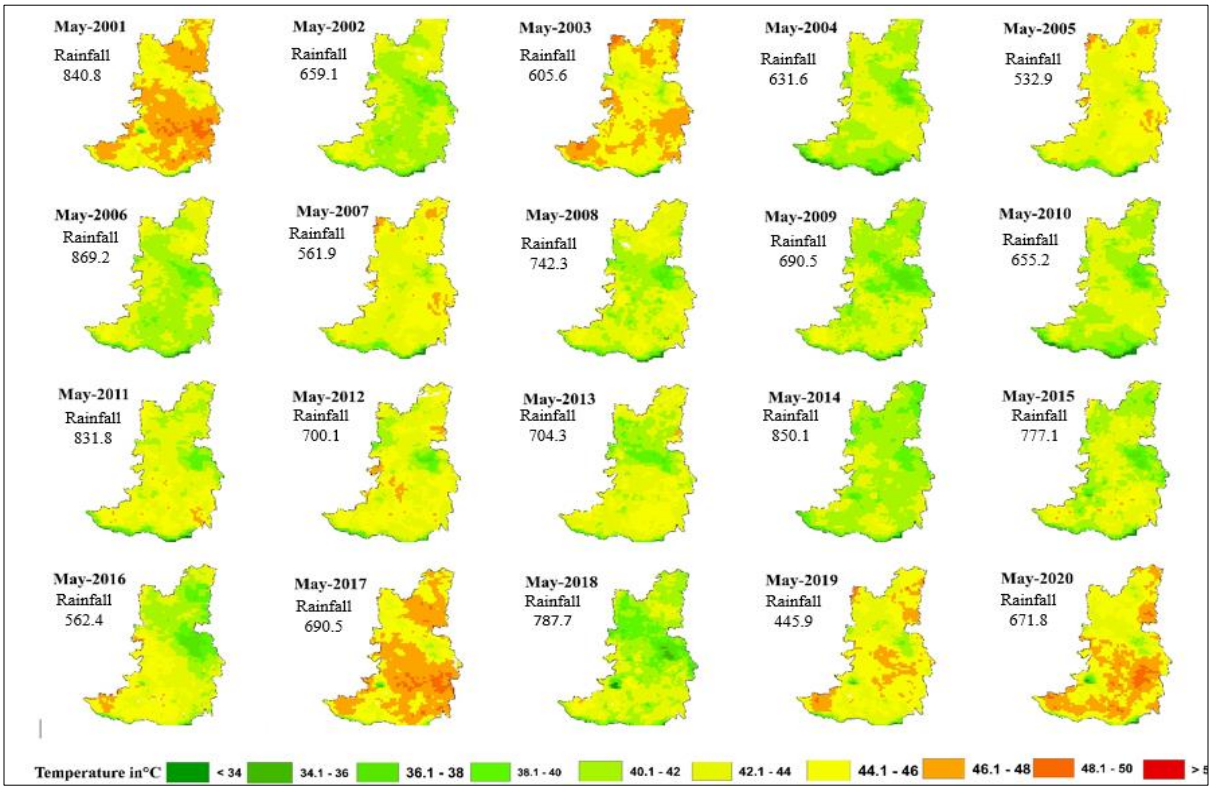
Narayanpet Average Land Surface Temperature in April, against the Annual Rainfall



Map 7: Land Surface Temperature of Naraynpet 2001-2020 of April

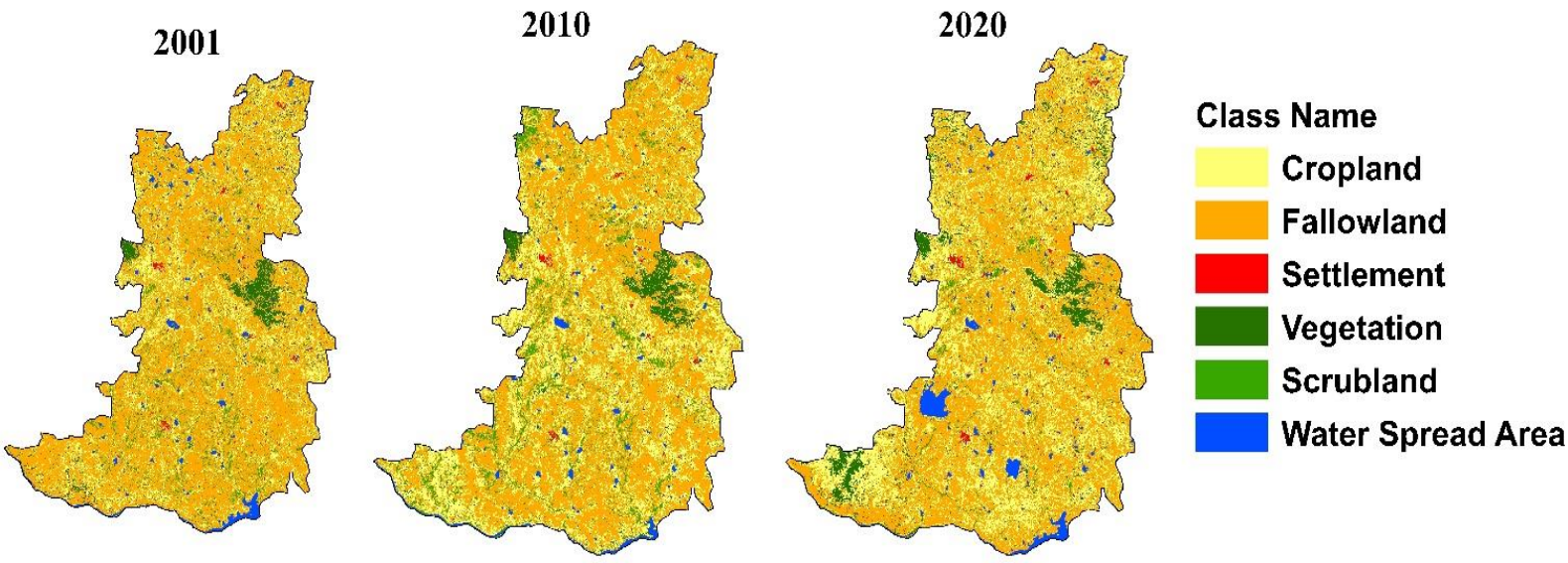
The map presents the land surface temperature variations of Narayanpet district for April from 2001 to 2020, highlighting significant temperature fluctuations over the years. The data reveals that in several years, particularly in 2002, 2013, 2016, and 2019, large portions of the district experienced extreme heat, as represented by the widespread red and dark orange regions where temperatures exceeded 48°C and sometimes surpassed 52°C. This suggests that April has been one of the hottest months, showing a distinct warming trend in specific years. The spatial distribution of temperature is not uniform, with the southern and southwestern parts of the district consistently exhibiting higher temperatures compared to other regions, which could be attributed to variations in land cover, topography, and vegetation. Yellow and green shades in some years indicate moderate temperature zones. Still, over time, these cooler areas seem to shrink, replaced by warmer shades, signaling a gradual temperature rise. The correlation between rainfall and temperature is also evident, as years with lower rainfall generally show more widespread heat zones, reinforcing the link between precipitation patterns and surface temperature. This visualisation highlights the impact of climate change and warming trends in the region, emphasising the need for proactive measures to mitigate the rising temperatures and their associated effects on agriculture, water resources, and overall living conditions in Narayanpet.

Narayanpet: Average Land Surface Temperature in May, against the Annual Rainfall



Map 8: Land Surface Temperature of Naraynpet 2001-2020 of May

The map illustrates the LST variations in Narayanpet from May 2001 to 2020, highlighting an overall increase in temperature trends over time. A significant observation is the presence of higher temperatures in May 2001, 2003, 2017, and 2020, where regions of intense heat, represented by orange and red shades, are more widespread. These elevated temperatures suggest potential drought conditions in those years, likely due to reduced rainfall and higher evaporation rates. The southern and southwestern parts of the district consistently exhibit higher temperatures, reinforcing the pattern of extreme heat in these regions. In earlier years, the maps predominantly featured green and yellow hues, indicative of moderate temperatures. However, the frequency and intensity of warmer shades, mainly orange and red, have increased significantly in recent years, signaling rising heat levels. This progressive warming aligns with the broader impacts of climate change, affecting agriculture, water resources, and overall ecosystem stability. The maps emphasise how May has become increasingly hotter, with fewer areas maintaining lower temperatures. The observed changes underscore the need for climate resilience strategies, such as improved water management, sustainable agricultural practices, and afforestation efforts, to mitigate the effects of rising temperatures in Narayanpet.



Map 9: Land Use and Land Cover Classification of Narayanpet 2001, 2010,2020

Class name	Area in Hectare		
	2001	2010	2020
Cropland	70164.66	51328.36	**77512.89**
Fallow land	136551.72	**156566.73**	131388.41
Vegetation	7399.98	10228.87	**12396.54**
Settlement	1161.46	1184.46	2558.66
Scrubland	16852.63	11539.82	6169.52
Water Spread Area	4139.85	5422.05	6244.27

Table 2: Statistics of Land Use and Land Cover Classification of Jalna 2001, 2010,2020

The LULC analysis of Narayanpet for the *rabi* season in 2001, 2010, and 2020 highlights significant changes in land utilisation over the years. One of the most prominent changes observed is the fluctuation in cropland. In 2001, cropland covered 70,164.66 hectares, which decreased to 51,328.36 hectares in 2010 but significantly expanded to 77,512.89 hectares by 2020. The year 2010 was a drought year, visible as a marked decrease in crop cultivated area.

Fallow land has undergone considerable variation over the two decades. In 2001, it occupied 1,36,551.72 hectares, which increased to 1,56,566.73 hectares in 2010 but then decreased to 1,31,388.41 hectares in 2020, because of the higher rainfall in 2020, as compared to 2010.

Vegetation cover has steadily increased over the years. In 2001, it was recorded at 7,399.98 hectares, rising to 10,228.87 hectares in 2010 and 12,396.54 hectares in 2020. This indicates a positive trend in afforestation, reforestation, or natural vegetation growth, which may contribute to ecological balance and biodiversity conservation.

The settlement area has also grown, reflecting population expansion and urban development. From just 1,161.46 hectares in 2001, settlements increased slightly to 1,184.46 hectares in 2010 but saw a more substantial rise to 2,558.66 hectares in 2020. This suggests an increasing demand for housing, infrastructure, and urbanisation.

Scrubland has experienced a significant decline. In 2001, it covered 16,852.63 hectares, reducing to 11,539.82 hectares in 2010 and shrinking to 6,169.52 hectares in 2020. The steady decline suggests that scrubland is being converted into agricultural land, settlements, or other land uses, indicating a transformation in land use patterns.

Water spread areas gradually increased from 4,139.85 hectares in 2001 to 5,422.05 hectares in 2010, reaching 6,244.27 hectares in 2020. This suggests improved water availability, possibly due to better water conservation measures, reservoir expansion, or increased rainfall.

Overall, the LULC changes in Narayanpeth indicate a dynamic transformation in land use patterns over the last two decades. The increase in cropland, settlements, and vegetation suggests growth and development, while the decline in fallow land and scrubland reflects land-use intensification. The expansion of water spread areas is a positive sign, potentially supporting agriculture and ecological sustainability in the region.

Conclusion:

This study clearly demonstrates that how we manage land directly influences how hot—or how habitable—our landscapes become. Over two decades, satellite data reveals that land use choices such as deforestation, intensive farming, or watershed development leave a measurable imprint on local temperatures. In vulnerable, semi-arid regions like Jalna and Narayanpet, these thermal shifts are not abstract—they affect water availability, crop productivity, and the very resilience of communities to climate extremes.

Land Surface Temperature (LST) is not just a scientific metric—it's a powerful early warning signal. By integrating LST monitoring into rural development and environmental policy, we can detect risks earlier, plan smarter, and act faster. This research offers a blueprint for how data-driven, localised interventions—whether afforestation, climate-resilient agriculture, or water conservation—can cool our landscapes and safeguard livelihoods.

In an era of accelerating climate change, the time to act is now. This study equips decision-makers, practitioners, and communities with insights to make more informed, climate-resilient land management choices—not just in Maharashtra and Telangana, but across India's climate-vulnerable regions.

Acknowledgement

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