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"SPATIO - TEMPORAL GIS ANALYSIS OF FOREST FIRE DISTRIBUTION AND LULC CHANGE DETECTION IN GIRWA TEHSIL, UDAIPUR (2018-2023)"

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Abstract: Forest fire is a major environmental concern affecting biodiversity, forest health, and ecological balance. In India, the frequency and intensity of forest fires have been steadily rising, particularly in ecologically fragile regions such as the Aravalli Hills in Rajasthan. This study aims to analyze the spatio-temporal assessment of forest fire occurrences and associated land use and land cover (LULC) changes in Girwa Tehsil of Udaipur District during the period 2018-2023. MODIS FIRMS active fire point data were analysed to evaluate the distribution and frequency of fire incidents, while hotspot analysis was carried out using overlay mapping to identify high-risk fire-prone zones. The results indicated that fire events were not uniformly distributed but clustered in specific belts, particularly the Sajjangarh-Badi forest corridor and parts of central Girwa, with peak five years recorded in 2019 and 2021. To understand the land transformation associated with recurrent fires, SAGA GIS was employed for supervised classification of Sentinel-2 imagery from 2018 and 2023. Comparative LULC mapping revealed a significant decline in dense forest cover and a corresponding increase in degraded or wasteland categories, along with slight expansion of built-up areas due to urban growth. The integration of fire hotspot mapping with LULC dynamics provides evidence that recurrent fires have accelerated vegetation degradation and land transformation in Girwa. The finding highlights the urgent need for proactive forest fire management, afforestation in degraded regions, and the integration of geospatial monitoring for sustainable ecological conservation.

Keywords: Forest Fire, MODIS FIRMS, Hotspot Mapping, SAGA GIS.

I. INTRODUCTION

Forest fire is recurring disturbance with profound ecological, environmental, and socio-economic implications. Globally, fire is recognized as both a natural phenomenon and a hazard that significantly alters vegetation, soil quality, and biodiversity. In India, forest fires account for extensive ecological losses every year. within Rajasthan the Aravalli Mountain ranges, despite being ecologically fragile, are highly susceptible to fire incident due to their dry deciduous forest type, prolonged summer season, and increasing human pressures. Girwa Tehsil, located in Udaipur district, forms part of this vulnerable zone where forest fire has become increasingly frequent over the last decade. Forest fires in Girwa are primarily seasonal, occurring during the dry months of March to June when moisture content in vegetation is minimal. These fires not only lead to long-term land degradation, habitat fragmentation, and biodiversity loss. While several studies have been conducted on forest fire risk zonation and vegetation impact assessment across India, there is limited research that integrates fire distribution with land use and land cover (LULC) change detection in Udaipur region. Understanding the dual perspective of fire hotspot analysis and land cover dynamics is critical for sustainable management of this ecologically sensitive zone. The present study, therefore has two major objectives: first, to analyze the spatio-temporal distribution of forest fires contribute to landscape transformation in Girwa.

II. STUDY AREA

Girwa Tehsil is located in the southern part of Rajasthan within Udaipur district, lying approximately between 24.5^0 N to 24.75^0 N latitude and 73.5^0 E to 74.0^0 E longitude, covering both urban and forested rural areas. Total area of Girwa tehsil is 1632.32sq km. The region is an integral part of the oldest fold mountains in the world and ecologically sensitive in nature. The topography of Girwa is marked by undulating hills, forested ridges, valleys, and seasonal streams. Important ecological zones such as the Sajjangarh Wildlife Sanctuary and the Badi forest belt fall within its extent, providing significant biodiversity and supporting native flora and fauna. The climate of the region is semi-arid, with scorching

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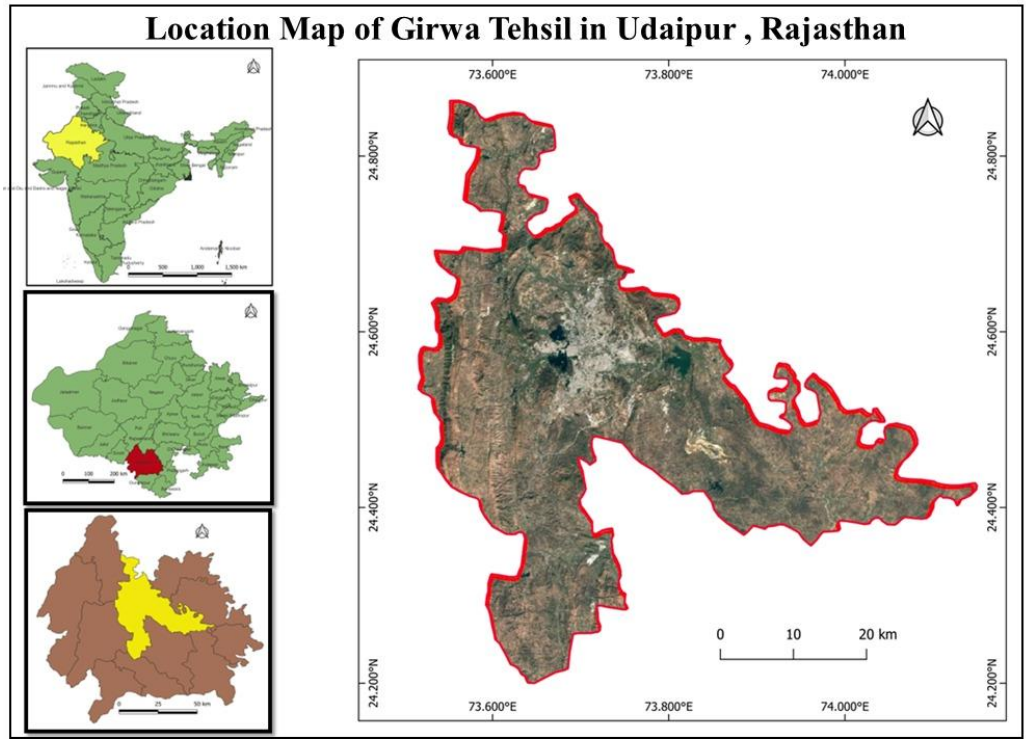
summers, moderate rainfall concentrated during the monsoon months, and cool winters. The region has a semi-arid climate with summer temperatures often exceeding 40^0C. Forests are dominated by dry deciduous vegetation, including species such as Dhonk, Teak, and Salai. These species, due to their deciduous nature, shed leaves extensively during the dry months, creating a large accumulation of dry biomass on the forest floor. This biomass acts as a fuel, making the forest highly vulnerable to fire during the summer season. Apart from natural conditions, several anthropogenic factors also contribute to the occurrence of fires in Girwa. Local communities are dependent on forests produce, leading to accidental fries. Agricultural practices such as stubble burning near forest fringes often spread into adjacent woodland areas. Tourism and recreational activities in and around Udaipur city, including campfires and negligence, further aggravate fire risks. In addition, urban expansion and infrastructure development disturb ecological balance, increasing forest vulnerability. Thus, the combined effect of natural and anthropogenic factors makes Girwa Tehsil highly prone to recurring forest fires, making it an ideal case study for spatio-temporal fire analysis and LULC change detection.



III. DATA AND METHODOLOGY

This study utilized both satellite-based and ancillary datasets to achieve its objectives. MODIS FIRMS fire point data for the years 2018-2023 were acquired from NASA to analyze fire occurrences in Girwa Tehsil. These data provide near real-time fire detection at a spatial resolution suitable for identifying hotspots and frequency of fire events. For land cover analysis, Sentinel-2A satellite imagery for the years 2018 and 2023 was used. SRTM DEM were employed to prepare base maps and elevation references, while administrative boundaries were obtained from the Bhuvan portal. The methodology followed a systematic framework. First, fire point data from FIRMS were processed in GIS software to create a year-wise fire frequency database. Overlay mapping was applied to identify major fire-prone hotspots across Girwa. Second, the Sentinel-2 images were pre-processed, including atmospheric correction, cloud masking, and image subsetting. Supervised classification using the Maximum Likelihood algorithm was carried out in SAGA GIS to classify the study area into five major land use categories: forest, agriculture, water bodies, built-up, and wasteland. Post-classification comparison between 2018 and 2023 was conducted to detect land cover changes. Finally, integration of fire hotspot data with LULC change maps was performed to assess the spatial relationship between recurring fires and land cover transformation. This approach provided both temporal (2018-2023) and spatial insights into how forest fires are influencing land degradation and altering land use patterns in Girwa.

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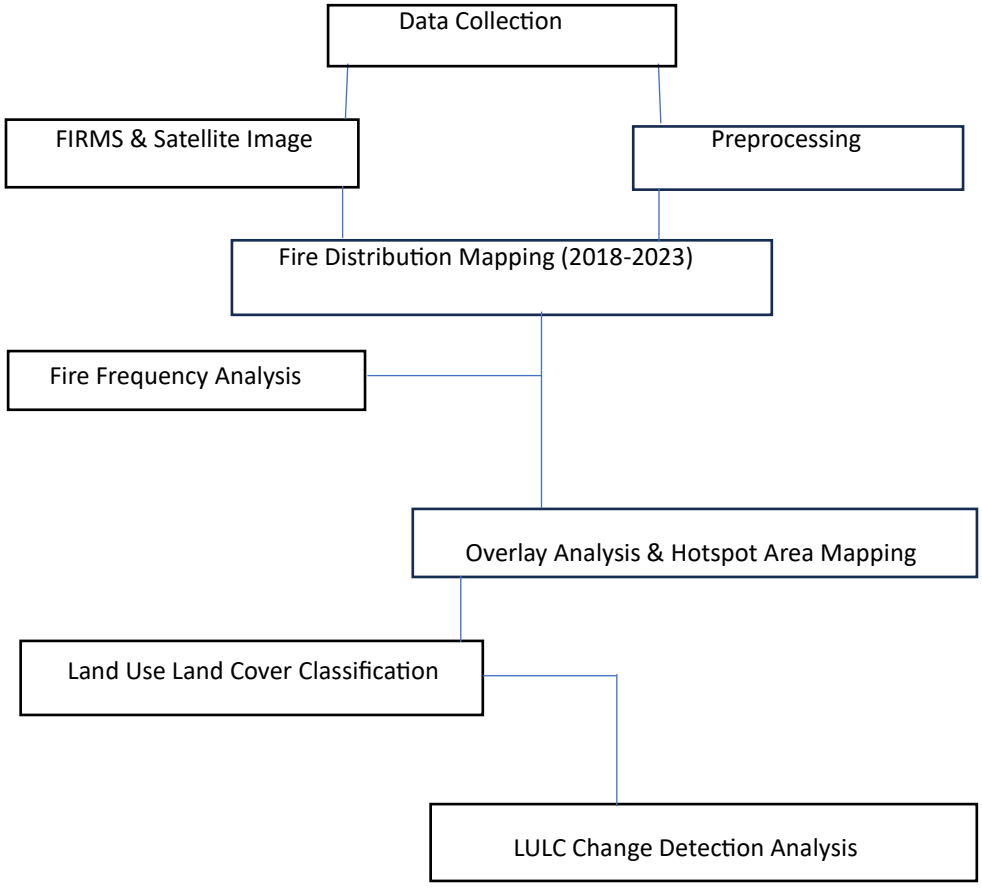

Flow Chart of Methodology

IV. RESULT AND DISCUSSION

Forest Fire Frequency (2018-2023): Analysis of MODIS FIRMS data from 2018 to 2023 reveals a total of 87 fire incidents in Girwa Tehsil. year-wise distribution showed considerable variation, with the highest numbers of fire points recorded in 2019 and 2021. Most fire points are spatially clustered around Badi, Sajjangarh forest hills, and west-central Girwa. Total fire affected area is 311.4 sq. km. These two years coincided with drier than usual pre-monsoon condition, which created favourable circumstances for fire ignition and spread. In contrast, year such as 2020 and 2022 showed comparatively fewer events, likely due to slightly better moisture conditions or successful preventive measures. The data highlights that fires in Girwa are not random phenomena but follow a seasonal pattern, with most incidents occurring between March and June. The corresponds to the period when deciduous trees shed their leaves and dry biomass accumulates, creating a highly flammable fuel bed. The recurrence of fires in certain years also points towards anthropogenic influences, particularly stubble burning and grazing practices in forest fringes. The overall frequency pattern suggests that forest fires are now an annual occurrence in Girwa, which is a cause of concern for the ecological stability of the region.

Year	No. of Fire Points	Total Area Affected (sq. km)	Notable Locations
2018	11	33.17	North & South
2019	11	34.51	South East
2020	9	26.87	South East
2021	17	69.46	South East
2022	11	21.79	South
2023	28	125.6	North to South
TOTAL	87	311.4	Central East

Fire Frequency Table

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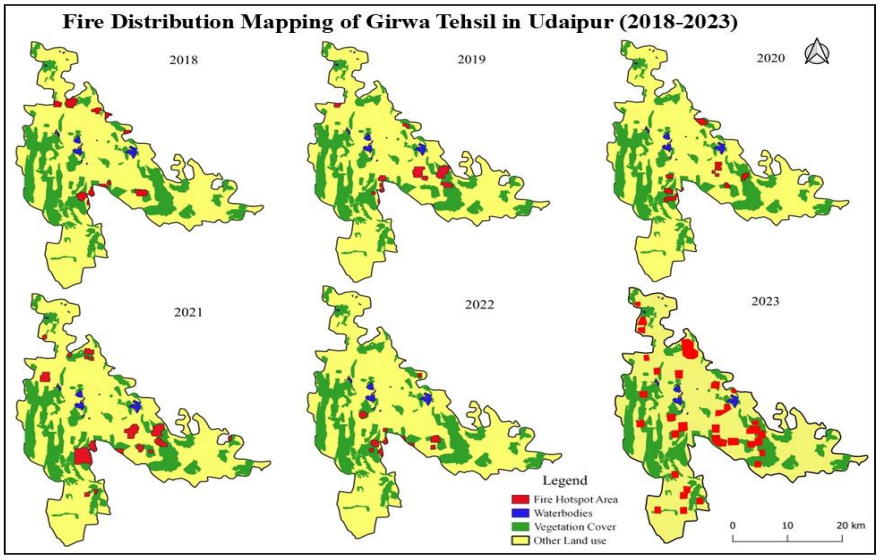
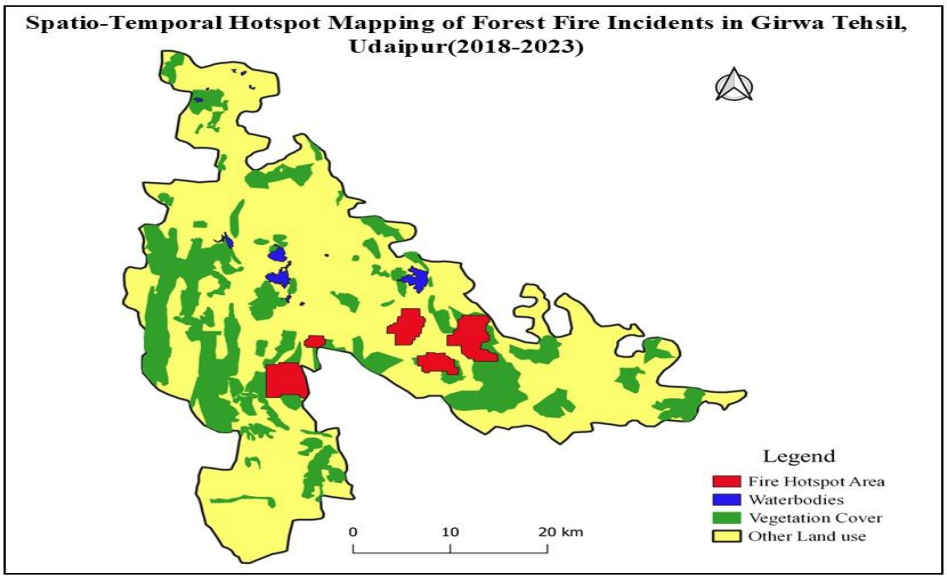
Fire Distribution Mapping: Mapping of fire points has done via FIRMS dataset in administrative boundary of Girwa tehsil, Udaipur district. Distribution mapping of Multi-temporal Fire point of 2018 to 2023 has created over land use map of study area. Shifting and occurrence of fire can be seen easily in map. fire points and area has been decreased from 2018 to 2023 and shifting of fire pattern from north and south to central & eastern region.



Hotspot Mapping: The spatial distribution of forest fires in Girwa Tehsil for the period 2018-2023 was examined using overlay analysis of MODIS FIRMS fire point data on the administrative boundary and land use maps of the region. Unlike kernel density Estimation, which generalizes the density of fire points, the overlay method directly displays the actual fire occurrences across the landscape and highlights the clusters where repeated events were recorded over multiple years. The overlay analysis revealed that fire points were not evenly scattered throughout Girwa but were but concentrated in specific belts. The Sajjangarh-Badi forest corridor emerged as the most vulnerable zone, showing repeated fire occurrences almost every year during the study period. This can be attributed to its dry deciduous vegetation, accumulation of leaf litter, and recreational activities. Another significant concentration of fire points was observed in central Girwa hills, where local anthropogenic activities such as fuelwood collection to frequent fire ignition. This overlays mapping approach not only allowed the identification of high- frequency fire zones but also facilitated a comparison with forested areas and degraded patches, indicating the strong role of fires in driving vegetation loss. By highlighting exact fire-prone locations, this method provides practical insights for site-specific fire management, resource allocation, and monitoring strategies. Thus, the overlay-based hotspot mapping confirms the persistence of localized high-risk zones in Girwa Tehsil and underlines the urgent need for preventive interventions.



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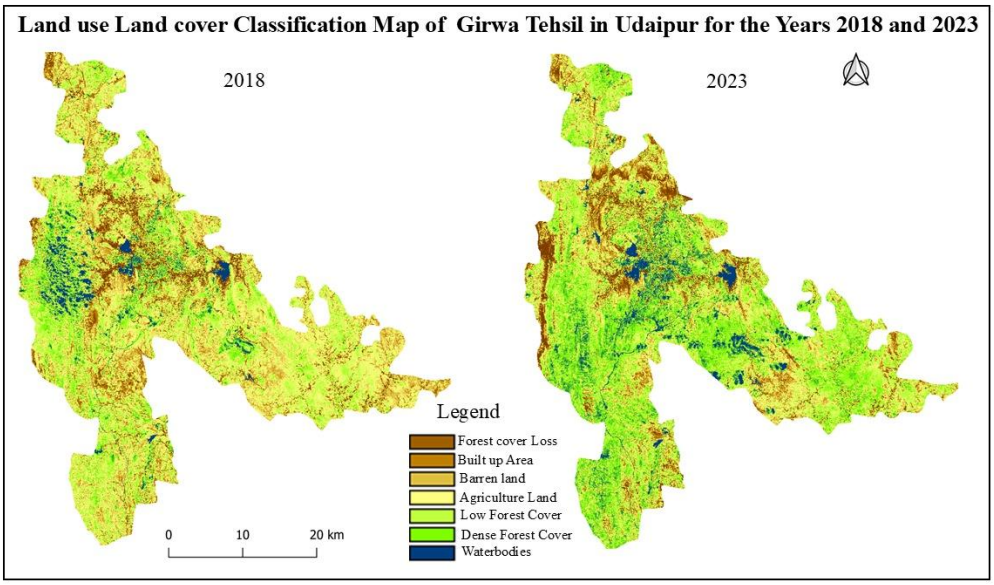
Land Use Land Cover Classification: LULC Classification 2018, The LULC map of Girwa Tehsil for 2018 shows that forest land was the dominant category. Agricultural land formed the second major class, supporting rural livelihoods and subsistence farming. Built-up areas were limited but concentrated around the urban fringes of Udaipur city and transport corridors. Water bodies, including Badi Lake and seasonal streams, occupied a relatively small proportion, while wasteland was scattered in degraded forest patches. LULC Classification BY 2023, significant changes were observed in land use land cover patterns. Forest cover declined and reflecting both natural degradation and the impacts of recurring fires. Agricultural land slightly reduced, suggesting conversion into either degraded land or expansion of built-up areas. Built up category showed a noticeable increase, attributed to urban expansion, tourism-related infrastructure, and population growth. Wasteland expanded substantially, confirming that recurring disturbances, particularly fires, hinder vegetation regeneration. Water bodies remained relatively stable with only minor variations.



LULC Change Detection (2018-2023): The comparatively analysis between 2018 and 2023 highlights the following transitions -

Forest ⟶ Wasteland: Large patches of forest degraded into wasteland due to repeated frie incidents.

Agriculture⟶ Built-up: conversion of fertile agricultural land near Udaipur city into built-up land.

Forest⟶ Agriculture: some forest fringes were encroached for cultivation.

Stable Zones: Water bodies remained almost constant with slight seasonal changes.

Three transformations indicate that Girwa Tehsil is undergoing a rapid shift from a predominantly forest-agriculture landscape towards a mosaic dominated by degraded land and built-up expansion. The spatial overlay with fire hotspot zones confirms that most forest loss and wasteland increase occurred in high fire recurrence areas such as Sajjangarh and Badi hills.

V. CONCLUSION

The present study carried out a spatial-temporal analysis of forest fire distribution and land use land cover changes in Girwa Tehsil, Udaipur District, for the period 2018-2023 using geospatial techniques. The results derived from MODIS FIRMS fire point data and hotspot mapping revealed that fire events in Girwa are not evenly distributed but spatially clustered, with persistent hotspots identified in the Sajjangarh-Badi forest belt and parts of central Girwa. The fire frequency analysis confirmed that the maximum fire activity occurred in 2019 and 2021, suggesting that Girwa has become highly vulnerable to seasonal fires during the dry pre-monsoon months. The LULC change detection using SAGA GIS for Girwa Tehsil between 2018 and 2023 demonstrates a clear trend of forest decline and wasteland expansion. The reduction in forest cover is strongly correlated with recurring fire incidents, while the increase in built-up land reflects the pressure of urban expansion from Udaipur city. Agricultural land shows minor reductions, partly due to urban encroachment and partly due to land degradation. The results confirm that forest fires are a primary driver of land cover transformation in Girwa, accelerating vegetation loss and converting ecologically rich zones into degraded land. The hotspot mapping of fire points corresponds closely with areas where forest was converted into wasteland, further emphasizing the link between fire frequency and land degradation. For sustainable management, it is recommended that: (1) Firebreaks and controlled burning measures be introduced in high-risk forest zones. (2) Degraded wasteland patches

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be prioritized for afforestation and soil conservation programs. (3) Urban expansion near forest edges be regulated to prevent further encroachment. (4) Community-based awareness programs be initiated to reduce anthropogenic fire causes such as stubble burning and fuelwood collection. In conclusion, the study highlights that without immediate intervention, Girwa Tehsil may experience further ecological imbalance, biodiversity loss, and irreversible land degradation. Geospatial monitoring through open-source platform like SAGA GIS proves to be an effective tool for timely detection and planning of mitigation strategies.

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