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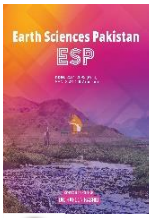

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RESEARCH ARTICLE

SPATIO-TEMPORAL ANALYSIS OF LAND USE AND LAND COVER CHANGES IN RESPONSE TO CLIMATE CHANGE IN DUGDA DAWA WOREDA, WEST GUJI ZONE, SOUTHERN ETHIOPIA

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ABSTRACT

Climate change has been identified as a primary driver of changes in land use and cover, resulting in negative impacts on the environment, biodiversity, and socioeconomic factors. This study looked at the spatiotemporal changes in land use and land cover in Dugda Dawa Woreda, Southern Ethiopia, as a result of climate change. The study used a combination of remote sensing, GIS analysis, and field surveys to analyze alterations in land use patterns across time. Agriculture, settlements, wetlands and grasslands, barren terrain, and forest regions were discovered and quantified using satellite imagery from various time periods. Climate data analysis indicated that from 1991 to 2021, average monthly temperatures ranged from 16.23°C to 24.43°C, with an average yearly temperature ranging from 19.18°C to 21.19°C. Rainfall varied by season, with larger quantities recorded in months such as August, July, September, June, May, and April. The study found that land cover percentages changed over time, with wetlands and grasslands accounting for 41.19% in 1990-2000 and agriculture accounting for 73.23% by 2000-2010. Climate, economic, and demographic variables influenced land use and land cover changes, resulting in challenges such as bare land expansion, increased runoff, and soil erosion. The study's recommendations underlined the need of sustainable land management methods in improving ecosystem resilience and combating the detrimental effects of climate change and land use changes.

KEYWORDS

Climate change, Dugda Dawa Woreda, Land use, Land cover change, Spatio-temporal variation

1. INTRODUCTION

Ethiopia has a diverse eco-environmental landscape, ranging from intense heat in one of the world's lowest points to one of Africa's coolest mountains. As a result of environmental diversity and climate change, climatic extremes are projected to alter throughout time and vary across the country's eco-systems. According to a study, the average global surface temperature has risen by 0.080C each decade since 1880, with the rate of warming more than doubling over the last 40 years, to 0.180C per decade since 1981 (Adamo et al., 2021). According to the Intergovernmental Panel on Climate Change, rising global temperatures cause abnormal global climate and extreme hydrological phenomena, resulting in frequent occurrences of hydrological extremes such as floods and droughts (IPCC, 2022). Changes in land use (human management and activities on land, such as mining or recreation) and land cover (physical features that cover the region, such as trees or pavement) can influence climate and vice versa (Feranec and Soukup, 2012).

Land use change is the primary driver of global environmental change, and it is regarded as essential to numerous discussions about sustainable development (Anumudu, 2019). Climate change influences land use through unpredictable heavy rainfall and rising temperatures. It also has an impact on precipitation, natural disasters including floods, storms, and droughts (Yesserie, 2009). Climate change's direct and indirect consequences, such as changed rainfall patterns, droughts, flooding, and the spatial dispersion of pests and diseases, have an adverse impact on agricultural output. Natural disasters such as floods, storms, and wildfires can result in the permanent loss of natural areas, particularly the loss of forests to urban or exurban development, or the loss of agricultural regions to urban or exurban development, which can result in a shift in the land's cover (Feranec and Soukup, 2012).

Climate change is projected to have a direct and indirect impact on land use and cover by changing disturbance patterns, species distributions, and land suitability for specific activities. Between 2000-2003 and 2016-2019, global farmland area rose by 11.5%, with Africa seeing the most growth, followed by Asia and South America (Gitima et al., 2022). Similarly, agriculture rose by 57%, while the country lost 5% of its woods and pastures and 16% of its forest area between 1975 and 2000 in Africa, with over 50,000 km2 of natural vegetation lost each year. The uplift was mainly intensive with the reduction of forests, bush, and grasslands in the Horn of Africa. However, the directions, rates, and intensities of LULCC in each land use type varied around the world (Gashaw et al., 2018). Most research have examined LULCC and its repercussions in various catchments.

The semi-arid Rift Valley Basin of Ethiopia is distinguished by rivers, lakes, and terrestrial habitats. In the basin, there is fierce competition for irrigation water, a reduction in natural forests, overgrazing, and steep slope farming (Gitima et al., 2022). In the basin, trends in LULC changes revealed losses in forest cover, soil erosion, crop production declines, sediment output, small lake drying up, and rising lake levels (Deche et al., 2023; Eyasu et al.,; Gessesew et al., 2019). Uncontrolled fluctuations

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in LULCC cause major environmental issues in many parts of the world (Gashaw et al., 2018). Land degradation, changes in biodiversity, and intensification of climate change on a global scale have all been related to LULC change, as has increasing stream sedimentation (Omran, 2015). Climate change is causing considerable changes in land use and cover in Southern Ethiopia, affecting both the environment and society. LULCC causes environmental disasters such as intensive loss of cropland soil and loss of millions of hectares of land (Hassen et al., 2021).

Changes in LULC can lead to soil erosion, which can have negative impacts on water resources and agricultural productivity (Belay and Mengistu, 2021). Population growth can worsen LULCC, putting severe pressure on land resources (Kuma et al., 2022a). Long-term urban LULCC dynamics and climate change patterns in Southwest Ethiopian cities have influenced local climate change, particularly surface temperature and precipitation. Monitoring and predicting changes in LULCC and their subsequent impacts on the environment and society are critical, Changes in LULC can be driven by a variety of factors, including demographic trends, climate variability, national policies, and macroeconomic activity, understanding the effects of LULCC and their driving forces in the Ethiopian Rift Valley region can help identify the interaction between the environment and society, mitigate the effects of environmental disasters and develop a plan for the use of natural resources (Dessu et al., 2020; Gedefaw et al., 2023). LULCC can cause socio-economic and environmental problems in Ethiopia and it causes environmental disasters such as intensive soil loss of cropland and loss of millions of hectares of land (Hassen et al., 2021; Elias et al., 2019). Most of these researches discovered that LULCC varies by country in terms of pattern, direction, and amplitude. However, the majority of the aforementioned research failed to take into account the dynamics of LULC in agro-ecological zones, as well as the impact of climate change on land use and land cover changes.

Understanding such changes can help design successful environmental policy and management plans for the studied area and surrounding region. As a result, with enough and current knowledge, regional and local leaders, planners, and policymakers may move forward with sustainable development. The timely delivery of relevant information on LULCC at various scales, including global, regional, and local, is critical for the successful implementation of international initiatives aimed at sustainable development, climate change mitigation, biodiversity conservation, and other goals outlined in the United Nations Sustainable Development Goals, the Paris Agreement, and the COP26 Glasgow Declaration, among others (Potapov et al., 2022). As a result, analyzing spatiotemporal land use and land cover change in response to climate change is critical for understanding the causes and impacts of LULCC, as well as establishing effective socioeconomic and natural resource conservation policies.

The purpose of this study was to look at the spatiotemporal differences in land use and land cover change (LULCC) caused by climate change in Dugda Dawa Woreda, Southern Ethiopia. The study examined changes in land use and land cover over a given time period, with the goal of identifying important drivers of change and their implications for the local environment and communities.

2. Materials and Methods

2.1 Description of the Study Area

Dugda Dawa is a woreda in Ethiopia's Oromia Region, specifically within the West Guji Zone. Historically, it was part of the Bule Hora Woreda. Located in the Great Rift Valley, Dugda Dawa shares borders with several zones and districts, including the Southern Nations, Nationalities, and Peoples' Region (SNNPR), the South West Shewa Zone, and the Arsi Zone. The administrative center of the woreda is Mecca. The region is predominantly characterized by a pastoral lifestyle, with some areas being semi-pastoral. According to the 2007 national census, Dugda Dawa had a population of 147,327, comprising 75,114 men and 72,213 women. Of these, 5,560 residents, accounting for 3.77% of the population, lived in urban areas. The woreda boasts significant agricultural and livestock production infrastructure. Dugda Dawa has a semi-arid climate influenced by its location in the Great Rift Valley and the impacts of climate change. The predominant soil types in the area include sandy loam and sandy loam with low moisture-holding capacity. The agroecology of Dugda Dawa is largely dominated by livestock farming, which is further supported by two additional farming systems in the West Guji Zone.

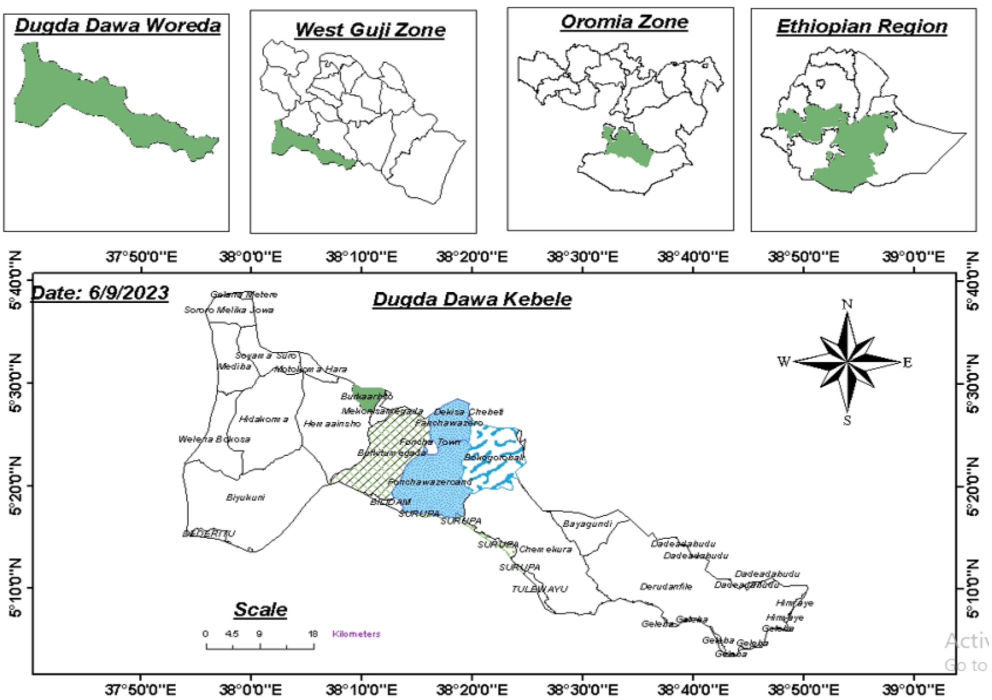

Figure 1: Map of the study area

2.2 Research Design

The study adopted a mixed parallel approach, predominantly quantitative, integrating both quantitative and qualitative research design methods. By merging these methodologies, the study aimed to provide a comprehensive and in-depth perspective on the research issues, leveraging diverse viewpoints to strengthen its arguments.

2.3 Primary Data Sources

Primary data were collected through a combination of observation, Key Informant Interviews (KIIs), and Focus Group Discussions (FGDs).

2.3.1 Key Informant Interviews (KIIs):

Sixteen key informants were interviewed, representing diverse backgrounds such as local community members, government officials, and Non-Governmental Organization (NGO) representatives. Key informants were selected based on specific criteria, including age (60 years or older), long-term residency (more than 30 years), and willingness to participate. Government officials and specialists from the Dugda Dawa Woreda Agricultural Office and the Dugda Dawa Woreda

Environmental Protection and Land Administration Office were included due to their expertise in land use dynamics. Selection of participants was purposeful to ensure relevance and depth.

2.3.2 Focus Group Discussions (FGDs):

Four FGDs were conducted, each involving seven participants, including elders, government administrators, and experts on the region's environmental challenges. Participants were chosen using the snowball sampling method from key kebeles, such as Burka Abicho, Fincha, Bokogorobali, and Burkitu Magada. These discussions facilitated the collection of diverse viewpoints on local environmental issues.

2.4 Secondary Data Sources

Secondary data sources, including government reports, published literature, and public statistics, were used to complement the primary data and provide additional insights into the magnitude and drivers of land use changes in the study area.

2.5 Data Acquisition

Secondary data were sourced from various organizations, including the Dugda Dawa Woreda Land Management and Environment Office, the Ethiopian Mapping Agency (EMA), the National Meteorological Agency of Ethiopia, and the Development Office. Satellite imagery was accessed via platforms like the LANDSAT Satellite Imagery Website and the US Geological Survey (USGS).

2.5.1 Processing and Analysis

Remote sensing technologies were utilized to quantify land use changes and their impacts. Socioeconomic data were collected through interviews and surveys, while satellite images were pre-processed with geo-referencing and geometric rectification techniques to ensure accuracy. The data were then processed, displayed, and analyzed to address the research objectives, particularly the spatiotemporal assessment of land use changes over time.

2.5.2 Climate Data

Environmental data, specifically precipitation and temperature records from 1991 to 2022, were sourced from the Ethiopian Meteorological Agency. Additionally, supplementary data were acquired from the USGS Earth Explorer portal.

2.5.3 Landsat Data

For analyzing land use/land cover changes over the past 30 years (1991 to 2023), data were obtained from historical Landsat satellite images. This included three 30-meter resolution TM satellite images for the study period. These images were acquired from the Global Land Cover Fund (GLCF) and the US Geological Survey (USGS), enabling detailed spatiotemporal analysis of land use dynamics within the research area.

Table 1: Land sat Images Data Reference

Reference years	Sensor	Resolution	Date of acquisition
1991-2000	Landsat TM	30m	August/22/2023
2000-2010	Landsat TM	30m	August /26/2023
2010-2023	Landsat 8	30m	August/28/2023

2.5.4 Image Processing

Digital image processing involves the manipulation and interpretation of digital images using computer systems to enhance their quality for display, interpretation, and extraction of valuable information. It primarily focuses on four basic operations: image correction and restoration, image transformation, image enhancement, and image classification. In this study, digital image processing was employed to improve the quality of data and support analysis.

2.5.5 Image Transformation

Image transformation was applied to modify the emotional connotations of problematic images or memories and to convert images from one spatial domain to another.

2.5.6 Image Classification

Image classification was used to extract distinct vegetation cover classes and land use categories from remote sensing data. For satellite imagery, preprocessing involved creating a color band composite using bands 4, 3, and 2 in RGB transformation. Georeferencing was performed to establish the correlation between row and column numbers and the actual geographic coordinates, ensuring spatial accuracy.

2.6 Data Analysis and Interpretation

To analyze the social and environmental impacts of changes within the study area, a combination of socioeconomic and environmental data was utilized.

2.6.1 Socioeconomic Data

Socioeconomic data were collected through household interviews in areas significantly affected by Land Use and Land Cover (LULC) changes. Additional insights were obtained from discussions with development agents, community elders, and focus groups comprising experts in agriculture, rural development, natural resource conservation, and land management. Data collected through Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) were qualitatively assessed and presented in a report format.

2.6.2 Environmental Data

Meteorological data, including rainfall and temperature trends, were analyzed using the **Mann-Kendall test** and **Sen's slope estimator**. The Mann-Kendall test was used to identify trends in annual and seasonal rainfall and temperature distributions during the study period.

2.6.3 Spatial Analysis

Geographic Information System (GIS) and **remote sensing techniques** were used for spatial monitoring and analysis, incorporating stakeholder knowledge. **ERDAS software** was employed for processing Landsat imagery, while **ArcGIS** facilitated geographical analysis, interpolation, and spatial computations. A supervised digital image classification method was adopted, supported by field surveys to validate land use categories and vegetation cover types.

2.6.4 Tools and Techniques

Data analysis was conducted using **Microsoft Excel (Windows 13)** and **SPSS-21** software. Landsat image data were analyzed using ERDAS software, while ArcGIS was used for further geographical computations. Data classification, chart development, and graph generation were carried out using ERDAS, GIS software, MS Office, and Excel.

3. Results and Discussion

3.1 Monthly Average Temperature of Dugda Dawa Woreda

Figure 2 illustrates the average monthly temperatures in Dugda Dawa Woreda from 1991 to 2021. The data reveals that the average temperatures in April and May were the highest compared to other months during this period. Conversely, November and December recorded the lowest average temperatures. The average monthly temperature across the 30-year span ranged between **16.23°C** and **24.43°C**, with a total temperature variation of **8.20°C** between the warmest and coolest months. Despite this range, the monthly temperature variance from 1991 to 2021 was minimal, indicating that the observed changes from month to month, and even within the same month across years, were relatively insignificant.

3.2 Average Yearly Temperature of Dugda Dawa Woreda

Figure 3 depicts the average yearly temperature in Dugda Dawa Woreda, West Guji Zone, from 1991 to 2021. The linear trend line for the mean temperature during this period is represented by an **R^2 value of 0.0003**, indicating a very minimal variance in the temperature trend over the three decades. The **R^2 value**, which measures the strength of the relationship between dependent and independent variables, is less than 0.5 due to the negligible variance observed.

Over the past 30 years, the average temperature shifted by **2.006°C**, with yearly averages ranging from **19.18°C** to **21.19°C**. The hottest temperature recorded was **21.19°C** in 2002, while the lowest temperature was **19.18°C** in 1991. These findings highlight a relatively stable temperature pattern with only minor variations over time.

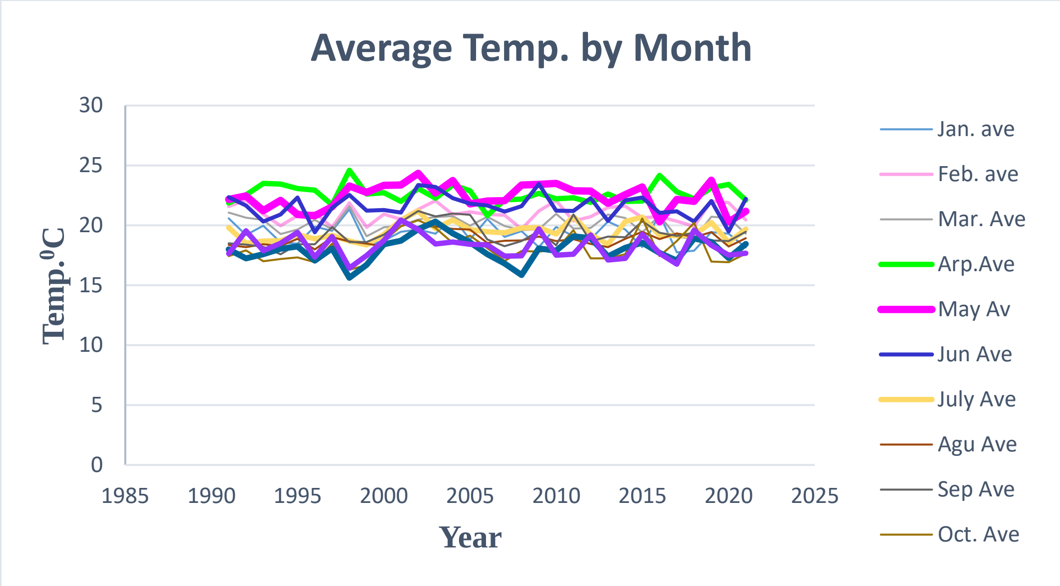

Figure 2: Average Temperature of DDW by month

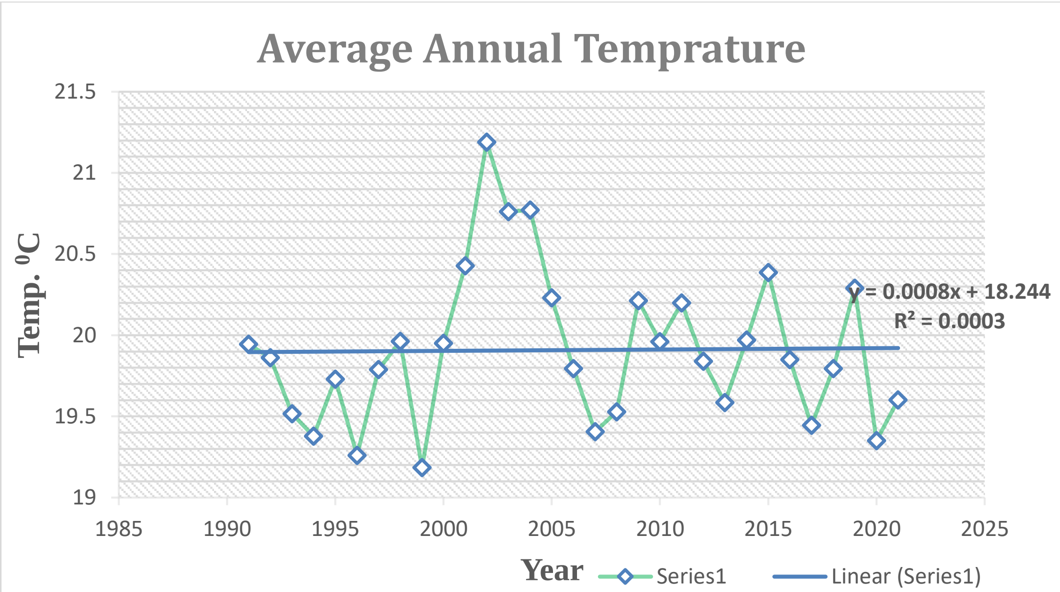

Figure 3: Average Annual Temperature of Dugda Dawa Woreda for 30 years

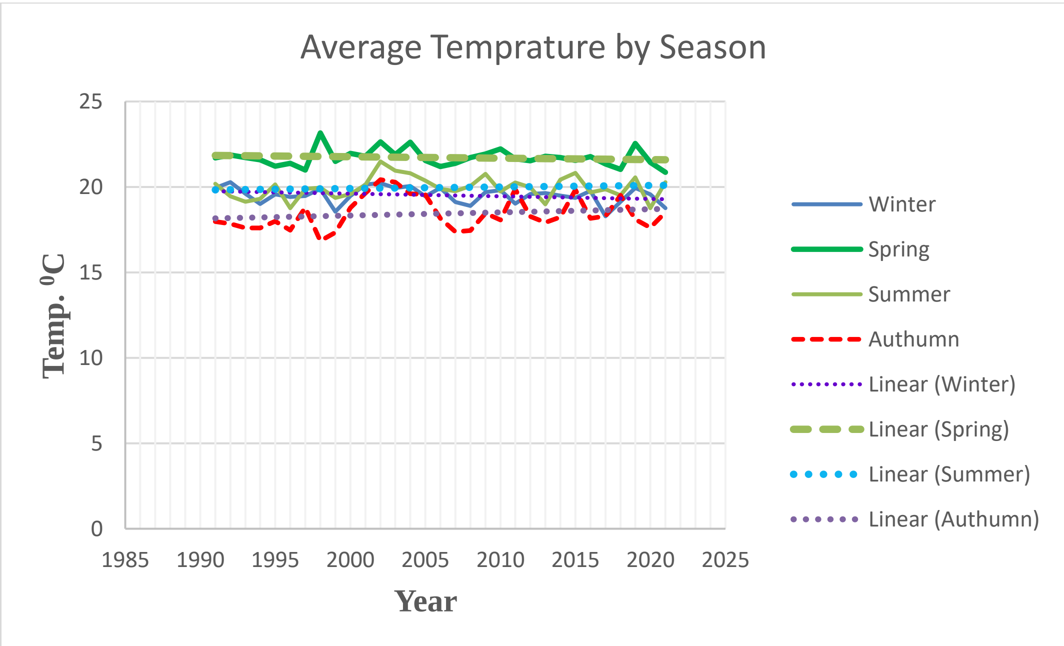

Figure 4: Average Annual Temperature of DDW by Season

3.3 Seasonal Average Temperature of Dugda Dawa Woreda

Figure 4 illustrates the seasonal average annual temperature trends in Dugda Dawa Woreda from 1991 to 2021. The data indicate that the highest temperatures occurred during the spring season, while the lowest temperatures were recorded in autumn. The summer and winter seasons exhibited intermediate temperature ranges, showing similar patterns and tendencies. Over the past three decades, the average seasonal temperatures were as follows: **Winter:** 19.52°C, **Spring:** 21.72°C (highest), **Summer:** 19.96°C, **Autumn:** 18.44°C (lowest). Despite being the lowest among the seasons, the autumn average temperature of 18.44°C remains relatively high compared to the typical temperatures of the **Dega**, **Woinedega**, and **Wurch** agro-ecological zones. The overall average temperature from 1991 to 2021 was **19.91°C**, indicating a consistently high temperature trend over the study period. Dugda Dawa experiences two dry and two rainy seasons, with considerable interannual variability in seasonal conditions (**Debela et al., 2015**). Local farmers in the Western Guji Plateau, including Dugda Dawa, are aware of climate change and its impacts on their livelihoods. However, existing studies lack specific details on how temperature changes affect the terrain. A study on the adaptation of maize cultivars to moisture-deficient areas in Dugda Dawa reported temperature ranges between **19°C and 33°C**, further highlighting the importance of temperature in shaping agricultural practices in the region (**Natol et al., 2018**).

The findings indicate that Dugda Dawa Woreda experienced notable seasonal and monthly variations in temperature over the last three decades. Average monthly temperatures ranged from 16.23°C to 24.43°C, with higher temperatures recorded in April and May and lower temperatures observed in November and December. The overall increase in average yearly temperatures by 2.006°C, from 19.184°C in 1991 to 21.190°C in 2021, highlights a warming trend consistent with regional climate patterns in Ethiopia (IPCC, 2023). This trend aligns with findings from other parts of the Ethiopian highlands, where significant warming has been observed over recent decades, particularly in semi-arid regions (Teshome et al., 2023). The spring season recorded the highest average temperature (21.716°C), while autumn had the lowest (18.439°C). These variations are critical, as higher temperatures during spring coincide with the early growing season, potentially stressing crops and impacting agricultural productivity. Such warming trends are linked to increased evapotranspiration, reduced soil moisture, and greater susceptibility to drought (Gashaw et al., 2022; Moisa et al., 2022). This has significant implications for livelihoods in Dugda Dawa, where agriculture is the dominant economic activity.

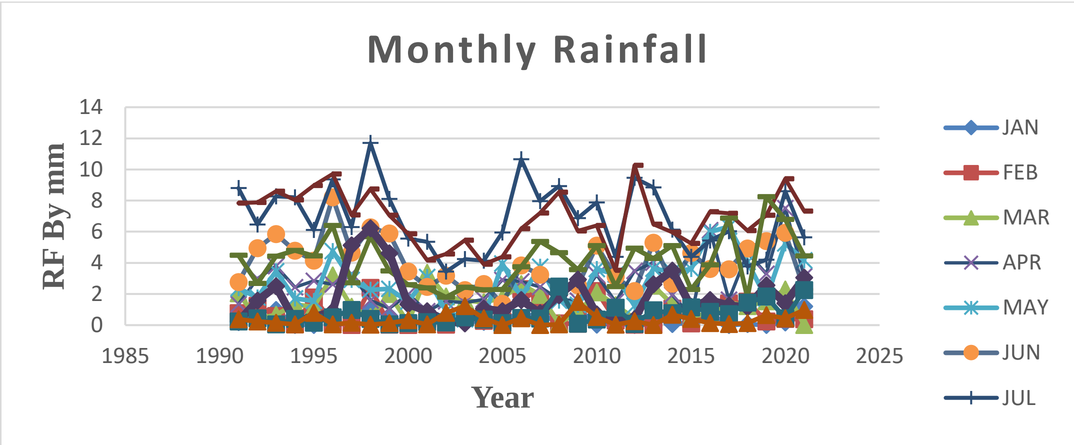

Figure 5: Average Monthly Rainfall of Dugda Dawa Woreda

3.4 Monthly Rainfall Patterns in Dugda Dawa Woreda

Figure 5 illustrates the monthly rainfall patterns in Dugda Dawa Woreda over the past three decades (1991–2021). The data reveal that, for most of the year, the region experienced less than 2 mm of precipitation per month, with a few notable exceptions. Higher rainfall levels were recorded during August, July, September, June, May, and April, with average monthly precipitation values of 6.85 mm, 6.81 mm, 4.08 mm, 3.99 mm, 2.84 mm, and 2.64 mm, respectively. Conversely, the months of December, January, November, and February received significantly less rainfall, with averages below 1 mm. The recorded precipitation for these months was 0.35 mm in December, 0.41 mm in January, 0.65 mm in November, and 0.67 mm in February. Overall, the study found that rainfall in Dugda Dawa Woreda was consistently insufficient to support sustainable agricultural production. The region faced persistent challenges due to inadequate rainfall and elevated water temperatures, which led to increased evaporation from reservoirs and further diminished water availability. These conditions underscore the vulnerability of the area to water scarcity and highlight the need for adaptive strategies to mitigate the adverse impacts of insufficient precipitation on agriculture and livelihoods.

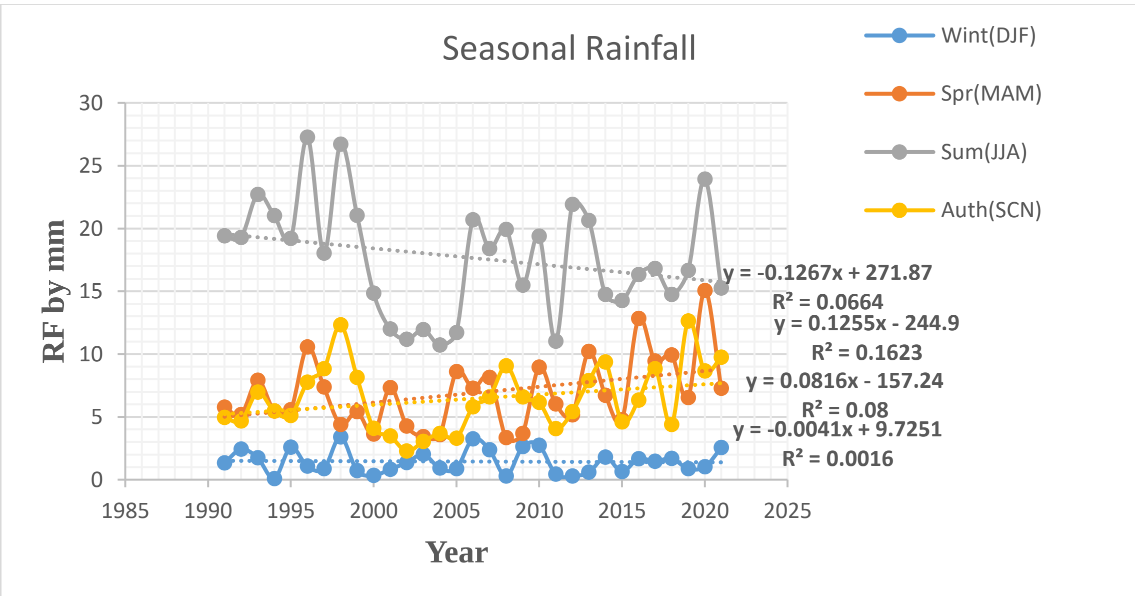

Figure 6: Seasonal Rainfall Dugda Dawa Woreda

3.5 Average Seasonal Rainfall in Dugda Dawa Woreda

Figure 6 illustrates the average seasonal rainfall in Dugda Dawa Woreda from 1991 to 2021. The data clearly indicate that summer experienced the highest average seasonal rainfall compared to other seasons, with an **R^2 value of 0.0664**. During this period, the average summer rainfall ranged from **22 mm** in 1996 to **10.5 mm** in 2004, marking a variability between these extremes over the last three decades. The overall average summer rainfall during this time was **17.65 mm**, significantly higher than rainfall levels recorded in other seasons. Conversely, the lowest rainfall was observed during the winter months of December, January, and February, with an average seasonal rainfall of only **1.44 mm**. This was followed by **6.45 mm** in autumn and **6.89 mm** in spring. These findings highlight significant seasonal variations in rainfall distribution, with summer contributing the most to the area's precipitation and winter the least.

The observed rainfall patterns emphasize the challenges posed by limited and uneven rainfall, particularly during critical agricultural periods. This variability underscores the need for effective water resource management and climate adaptation strategies to support sustainable livelihoods in Dugda Dawa Woreda.

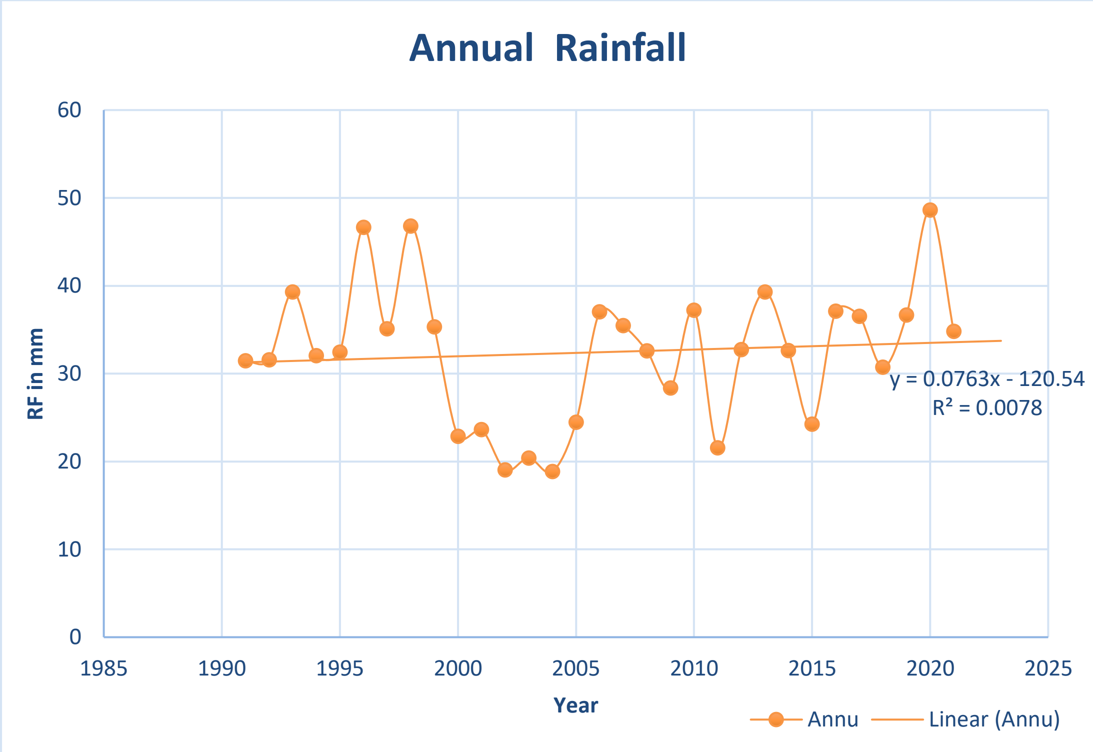

Figure 7: Annual Rainfall

3.6 Annual Rainfall of Dugda Dawa Woreda

Figure 7 illustrates the average annual rainfall trends in Dugda Dawa Woreda over the last three decades. The data reveal significant year-to-year fluctuations in rainfall levels. The lowest annual rainfall was recorded during the period from 2002 to 2004, with averages of **18.85 mm in 2004**, **19.04 mm in 2002**, and **20.39 mm in 2003**. Conversely, the highest annual rainfall was observed in 1996, 1998, and 2020, with **48.63 mm in 2020**, **46.81 mm in 1998**, and **45.70 mm in 1996**. These variations reflect a trend of modest increases in rainfall, as shown by the linear trendline with an **R^2 value of 0.00078**, indicating minimal variation over time. Farmers in the Western Guji Plateau, including Dugda Dawa, consider shifts in rainfall patterns a critical factor affecting agricultural productivity. Research by a group researchers found that maize cultivars in Dugda Dawa Woreda, particularly in the lowland areas, are well-adapted to the region's rainfall conditions (Natol et al., 2018). However, the fluctuating rainfall patterns have significant implications for the livelihoods of the local pastoralist communities, making water resource management and adaptation strategies essential (Worku, 2020).

Rainfall in Dugda Dawa Woreda is both seasonal and insufficient, with significant interannual variability. The study revealed that summer months (June–August) received the highest rainfall, with an average of 17.65 mm over the study period, while winter months (December–February) had the lowest rainfall (1.44 mm). The erratic nature of rainfall, characterized by periods of intense precipitation followed by prolonged dry spells, poses challenges to agricultural production and water resource management. The findings are consistent with studies from other parts of Ethiopia, which report declining rainfall trends in critical agricultural seasons and an increase in the frequency and intensity of extreme weather events (Mekonnen and Tadesse, 2023). For example, the lowest annual rainfall recorded in Dugda Dawa (18.85 mm in 2004) coincided with a period of significant agricultural challenges, including crop failures and reduced livestock productivity. This variability in rainfall exacerbates soil erosion and contributes to land degradation, as heavy rainfall events result in rapid runoff on deforested and degraded lands (Potapov et al., 2022).

3.7 Land Use and Land Cover Changes in Dugda Dawa Woreda

Land use and land cover changes in Dugda Dawa Woreda have undergone significant transformations over the past decades. These changes are categorized into various types, including **forest**, **farms**, **settlements**, **wetlands**, **grasslands**, and **bare ground**. From **1990 to 2000**, wetlands dominated the southeastern part of the woreda, as shown in Figure 8. During the **2000 to 2010** period, agricultural activities became the predominant land use, while settlement areas occupied a smaller proportion compared to other categories (Figure 9). In the subsequent period from **2010 to 2023**, a significant portion of the woreda was dedicated to agricultural activities, with bare ground and settlement areas expanding notably. Forested regions, however, were reported to occupy a smaller area compared to other land use categories, as depicted in Figure 10.

3.8 Land Use and Land Cover Change (1990–2023)

The land use and land cover analysis revealed significant shifts in land use patterns in Dugda Dawa Woreda over the last three decades. Wetlands and grasslands, which dominated the southeastern portion of the woreda in 1990 (41.19%), declined drastically to 8.61% by 2023. Simultaneously, agricultural land expanded from 26.80% in 1990 to a peak of 73.23% in 2010, followed by a decline to 54.20% in 2023. Forest cover also decreased from 1.77% in 1990 to 0.17% in 2010 but rebounded slightly to 6.27% in 2023, due to reforestation initiatives under Ethiopia's Green Legacy Program (Mariye et al., 2022). The expansion of agricultural land is attributed to population growth and increased demand for food, a trend observed across Ethiopia (Teshome et al., 2023). However, the unsustainable conversion of wetlands, grasslands, and forests into agricultural land has resulted in significant environmental consequences, including soil erosion, loss of biodiversity, and the depletion of water resources (Gashaw et al., 2022). For instance, the transformation of 23.64% of dense forest cover into cropland in the Dedo River Basin highlights the widespread impacts of such changes on natural ecosystems (Potapov et al., 2022).

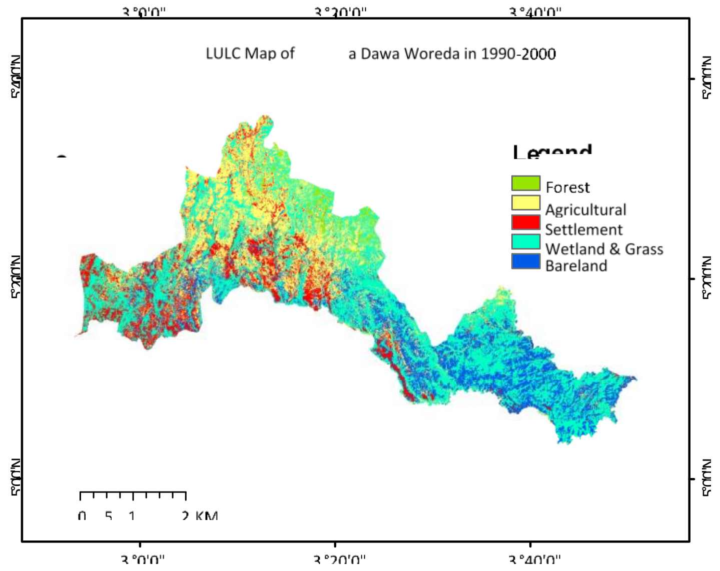

Figure 8: LULC of Dugda Dawa woreda in 1990-2000

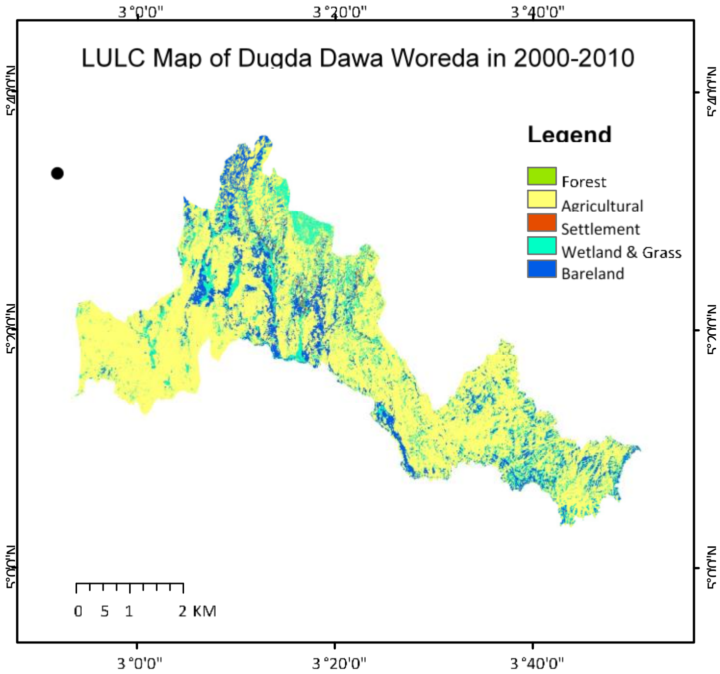

Figure 9: LULC of Dugda Dawa woreda in 2000-2010

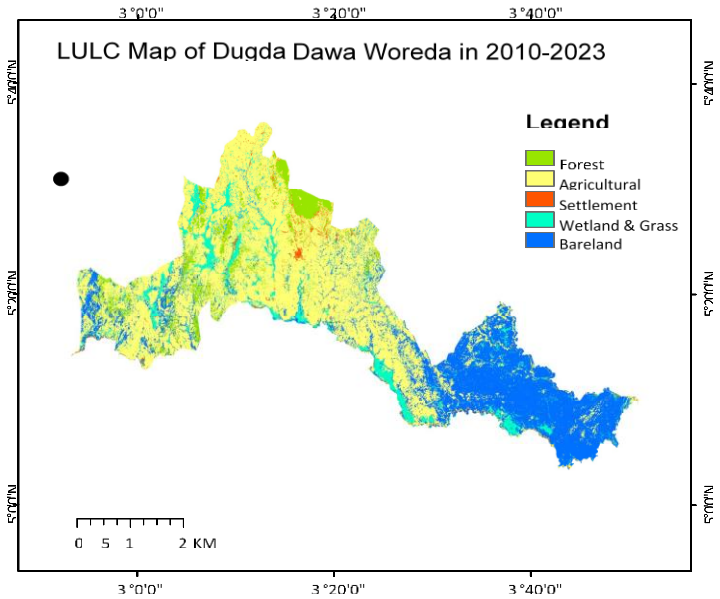

Figure 10: LULC of Dugda Dawa woreda in 2010-2023

Table 2: LULC of Dugda Dawa Woreda in Showing Area Coverage Change

LULC type	1990-2000		2000-2010		2010-2023	
	M²	%	M²	%	M²	%
Forest	32264.1	1.77	3062.7	0.17	114321	6.27
Agriculture	487857	26.8	1337366	73.23	989870	54.20
Settlement Area	241629	13.23	12853.8	0.70	34397.1	1.9
Wetland & Grassland	752194	41.19	251450	13.78	157329	8.61
Bareland	312091	17.09	221303	12.11	530119	29.03
Total	1826035	100	1826035	100	1826035	100

Table 2 illustrates the changes in land use and land cover (LULC) in Dugda Dawa Woreda over three distinct periods: 1990-2000, 2000-2010, and 2010-2023. Between 1990 and 2000, wetlands and grasslands covered a significant portion of the land, followed by farmland, bare ground, and forests. Residential areas accounted for the smallest proportion of land use. However, between 2000 and 2010, agricultural land saw a dramatic increase, covering 73.23% of the area, followed by wetlands and grasslands (13.78%), fallow land (12.11%), residential areas (0.70%), and forests (0.17%). During this period, the coverage of wetlands decreased from 41.19% to 13.78%, while agricultural land expanded substantially from 26.8% to 73.23%. The coverage of residential areas dropped sharply from 13.23% to 0.70%, and forested areas decreased from 1.77% to 0.17%.

From 2010 to 2023, forest cover increased to 6.27%, agricultural land reduced to 54.20%, and bare land increased significantly to 29.03%. Wetlands and grasslands also saw a reduction to 8.61%, while residential areas grew slightly to 1.9%. Notably, forest cover fell from 1.77% to 0.17% between 1990 and 2010, but then rebounded to 6.27% between 2010 and 2023. Agricultural land expanded from 26.8% to 73.23% between 1990 and 2010, before decreasing to 54.20% by 2023. Residential area coverage dropped from 13.23% to 0.7% between 1990 and 2010, then increased to 1.9% from 2010 to 2023. The coverage of wetlands and grasslands showed a continuous decline from 41.19% in 1990 to 8.61% in 2023. Bare land accounted for 17.09% of the area between 1990 and 2000, decreased to 12.11% by 2010, and then rose to 29.03% by 2023.

A study conducted in the Mokonisa Machi Watershed in Dugda Dawa Woreda highlighted how land use changes have affected plant nutrient availability and soil carbon reserves. The study identified rapid population growth and long-standing agricultural practices as primary contributors to environmental degradation in the region (Urgessa and Ferede, 2023; Fikadu and Olika, 2023a). Similarly, research on land use and land cover change in the Dedo River basin of southwestern Ethiopia found that improper agricultural practices, overgrazing, population growth, and weak institutional frameworks were significant drivers of land degradation. The study revealed that the area of dense forest cover decreased from 22.48% in 1984 to 17.95% in 2000, and remained around 13.27% by 2017. Between 1984 and 2000, about 23.64% of dense forest cover was converted to cropland, with additional portions changing to light vegetation (Anteneh, 2022). A study of smallholder farmers in the West Guji Plateau, including Dugda Dawa, found that changes in land use and land cover were key factors impacting agricultural productivity. The LULC changes in Dugda Dawa have had profound implications for natural resources and the livelihoods of local communities. The reduction in forest and wetland areas has led to soil erosion, reduced soil fertility, and diminished water retention capacity, thereby impacting agricultural productivity which are in align with the studies (Moisa et al., 2022). Overgrazing and unsustainable farming practices have further degraded the land, making it less productive for both crops and livestock. Similar findings from the Mokonisa Machi Watershed in Dugda Dawa highlight the link between population growth, sedentary agriculture, and environmental degradation (Mekonnen and Tadesse, 2023). Pastoralist communities in Dugda Dawa, who rely heavily on grasslands for livestock grazing, are particularly vulnerable to these changes. The depletion of grazing resources and declining water availability have forced many to adopt less sustainable practices, such as expanding agricultural land into marginal areas. These shifts exacerbate land degradation, creating a feedback loop of reduced productivity and increased environmental stress (Teshome et al., 2023; Kamwi et al., 2018). Climate change is a key driver of the observed LULC changes in Dugda Dawa Woreda. Rising temperatures and erratic rainfall patterns have increased the vulnerability of the region's ecosystems and agricultural systems. The conversion of grasslands and wetlands into bare land is directly linked to climate-induced stress, such as prolonged droughts and increased evapotranspiration (Kuule et al., 2022). This aligns with findings from the Nyangatom area in southwestern Ethiopia, where climate change has been identified as a major driver of LULCC in pastoral areas (Gebeyehu et al., 2023; Gashaw et al., 2022).

4. Conclusion

In conclusion, the analysis of land use and land cover (LULC) changes in Dugda Dawa Woreda, Southern Ethiopia, from 1991 to 2023 highlights the profound impact of both climate variability and human activity on the landscape. Rising temperatures and slight declines in rainfall have exacerbated land degradation, soil erosion, and ecosystem vulnerability, underscoring the delicate balance between climate and land management practices. Forest cover, which experienced a sharp decline from 1.77% in 1991–2000 to 0.17% in 2000–2010, has seen some recovery due to reforestation efforts under the Green Legacy Program, but remains below historical levels, signaling the need for continued conservation efforts. Agricultural expansion fueled by population growth reached 73.23% in 2000–2010 but has since decreased to 54.20%, likely due to the negative impacts of soil degradation and reduced fertility. The significant reduction of wetlands and grasslands, from 41.19% in 1991–2000 to 8.61% in 2010–2023, reflects the conversion of these ecosystems to agricultural land, compounded by climate-induced drying. Meanwhile, bareland coverage increased steadily, driven by overgrazing, deforestation, and changing climatic conditions. The fluctuating trends in settlement areas further emphasize the shifting dynamics of land use in response to population pressures and urbanization. These findings point to the growing stress on the region's natural resources and ecosystems, driven by both human-induced factors such as agricultural expansion and overgrazing, and climate change. To address these challenges, the study calls for urgent and integrated land management strategies, including soil conservation, sustainable agriculture, and reforestation efforts, to combat land degradation and ensure the long-term resilience of ecosystems and local livelihoods. Implementing these strategies will require coordinated policy interventions and community involvement to halt further degradation and foster sustainable development. Future research should focus on the long-term impacts of these LULC changes on biodiversity, water resources, and socio-economic systems to inform more effective interventions for the region's sustainable future.

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