6th Intercontinental Geoinformation Days

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# Analysis of land surface temperature distribution in response to land use land cover change in agroforestry dominated area, Gedeo Zone, Southern Ethiopia

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**Keywords**
Agroforestry
Gedeo Zone
Land Surface Temperature
Support Vector Machine

**Abstract**

Land Use Land Cover (LULC) changes have a significant impact on Land Surface Temperature (LST) by altering the surface properties and energy balance. The current study aimed to analyze the LST distribution due to LULC change over the agroforestry-dominated Gedeo Zone, Southern Ethiopia. Multi-temporal satellite images acquired by Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 using OLI-TIRS sensors in 2005, 2011, and 2017, respectively, and a Sentinel 2A MSI in 2017 and 2022 were corrected for radiometric using and geometric errors and processed to classify LULC classes and extract LST. The study result revealed that the temperature varies through the surface according to LULC classes. It was identified that the Agroforestry and Built-up coverage has increased by 1520 and 2600 km$^2$, respectively, from 2005 to 2022. On the other hand, the Bare Land and Farm Land coverage decreased by 1554 and by 2565 km$^2$, respectively, in the same period. The LST result has shown that there has been a remarkable variation in the spatial pattern of the LST between 2005 and 2022. The average LST in Agroforestry, Bare Land, Farm Land, and Built-up area has progressively increased over the years, from 19.6, 26, 20.2, and 25.58 $^0$C in 2005 to 25, 32.16, 28.23, and 30.62 $^0$C in 2022, respectively. While in 2005 the maximum recorded LST did not exceed 37.3°C, by 2022 it had increased by close to 3°C, reaching 40.6°C. Even though the coverage of Agroforestry has increased in the last 17 years, the mean LST has increased. From the result, it was concluded that LST may not be dependent on the local LULC change only; other factors like urbanization and global warming could play a significant role in changing LST locally as well as globally. So, the results of this study are important

## 1. Introduction

Land Use Land Cover (LULC) changes can have a significant impact on Land Surface Temperature (LST) by altering the surface properties and energy balance(Govind & Ramesh, 2019; Tan, Yu, Li, Tan, & Zhou, 2020). Studies showed the conversion of forested areas to agricultural land results in a decrease in evapotranspiration and an increase in surface temperature due to reduced vegetation cover and increased soil exposure(Bounoua, DeFries, Collatz, Sellers, & Khan, 2002; Defries, Bounoua, & Collatz, 2002; Pramova, Locatelli, Djoudi, & Somorin, 2012).

Land surface temperature (LST) is a measure of the surface temperature of the Earth, and it is an important variable in climate modeling and environmental monitoring(Hulley et al., 2019). It is affected by various factors, including solar radiation, air temperature, humidity, wind speed, and surface properties such as albedo and emissivity(Hofierka, Gallay, Onačillová, & Hofierka Jr, 2020).

Even though several studies were conducted to observe the impact of LULC change on LST, the extent and direction of these changes remain poorly understood, and there is a need to investigate the impact of LULC on LST in the agroforestry-dominated Gedeo Zone.

## 2. Method

### 2.1. Study area

The study was conducted in the Gedeo zone Southern Nations Nationalities and Peoples (SNNP) region, Ethiopia. Geographically, the study area is located

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**Cite this study**

Sahile, W. T., Goshem, G. K., Shifaw, S. E., & Abidin, M. R. (2023). Analysis of land surface temperature distribution in response to land use land cover change in agroforestry dominated area, Gedeo Zone, Southern Ethiopia. Intercontinental Geoinformation Days (IGD), 6, 424-427, Baku, Azerbaijan

from 5°53' N to 6°27' N latitude and from 38° 8' to 38° 30'E longitude. The altitude ranges from 1500 to 3000 m above mean sea level. The area experiences annual rainfall that ranges from 800 to 1800 mm and the mean annual temperature varies from 12.5°C to 25°C (Negash, Yirdaw, & Luukkanen, 2012).

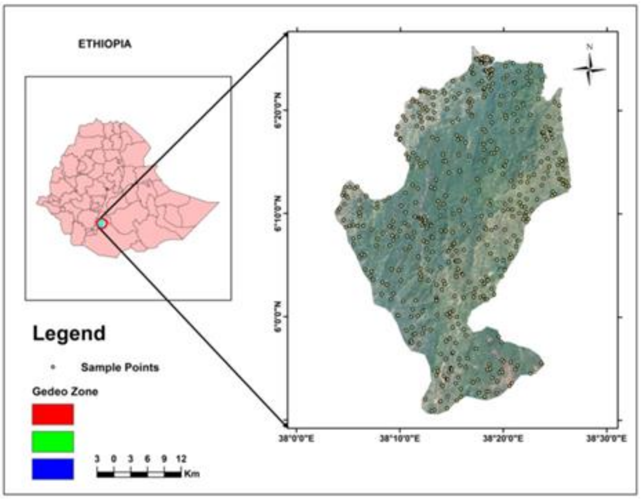


**Figure 1.** Study Area

## 2.2. Data

Two years of Cloud-free Sentinel-2A MSI images were downloaded from European Space Agency (ESA) website for land use land cover classification in 2017 and 2022. Sentinel image has a 10 m spatial resolution relatively higher resolution than Landsat images. To address the study area extent, three scenes of sentinel images were mosaicked and subsetted to the study area extent. Additionally, four different years of Landsat imageries with a path/row 168/56 were downloaded from the USGS-EROS website (https://eros.usgs.gov/) for land cover classification and LST extraction. A 1.5 m and 5 m spatial resolution Spot images and Google Earth historical images were utilized for assessing the accuracy of classification for 2005, 2011, and 2017.

**Table 1.** Data and Data Source

| Sensor Name | Acquisition Date | Spatial Resolution (m) | Source |
|---|---|---|---|
| ETM+ | 01/01/2005 | 30 | USGS “ |
| “ | 01/01/2011 | “ | |
| OLI_TIRS | 01/01/2017 | “ | “ |
| “ | 01/01/2022 | “ | “ |
| Sentinel 2A | 01/01/2017 | 10 | ESA |
| “ | 01/01/2022 | | |
| Spot 5 | 2005 | 5 | GII |
| Spot 7 | 2017 | 1.5 | “ |

## 2.3. LULC mapping and accuracy assessment

Before starting the classification, all stated satellite images' atmospheric errors were corrected by applying Dark Object Subtraction (DOS1) method under the preprocessing tool in Quantum GIS 3.10. The land cover maps for the years 2017 and 2022 were derived from 10 m reflective bands of Sentinel 2A and 30 m Landsat 7, and 5 images for the years 2005 and 2011 using a Support Vector Machine (SVM) classification algorithm. The SVM is a commonly used supervised machine learning algorithm that is widely used for classification techniques for image classification(Foody & Mathur, 2004).

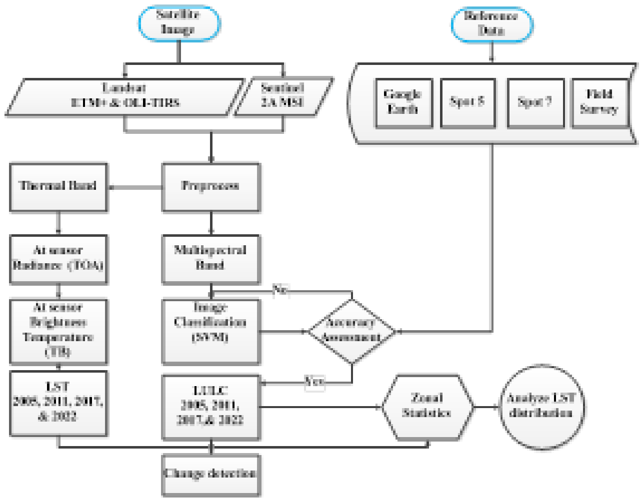


**Figure 2.** Methodology Flowchart

## 3. Results

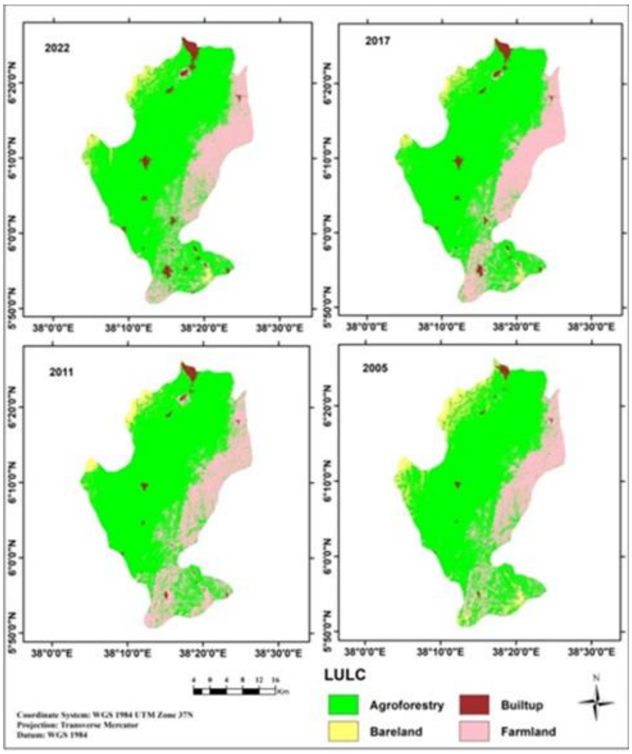
### 3.1. Spatio-temporal distribution of LULC in Gedeo Zone between 2005 and 202

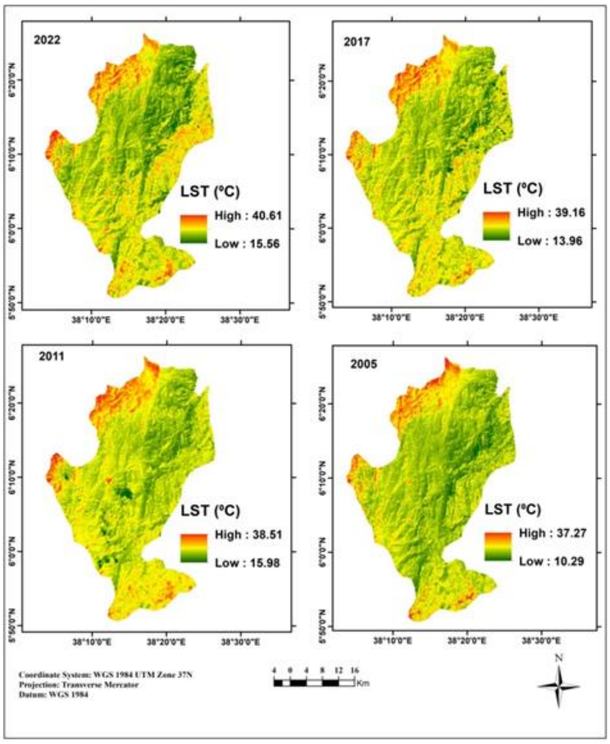
We can observe that the area of Agroforestry has increased steadily from 104,071 km$^2$ in 2005 to 105,591 km$^2$ in 2022. On the other hand, the Bare-land area decreased from 6725.7 km$^2$ in 2005 to 4163.13 km$^2$ in 2011, but it slightly increased again to 5169.78 km$^2$ in 2022 indicating the efforts to reforest and restore degraded lands have been partially successful. The built-up area has consistently increased over the years, from 1092.6 km$^2$ in 2005 to 3693.87 km$^2$ in 2022. The area of Farmland has been decreasing over the years, from 36,515.7 km$^2$ in 2005 to 33,950.3 km$^2$ in 2022 at the expense of other LULC changes.

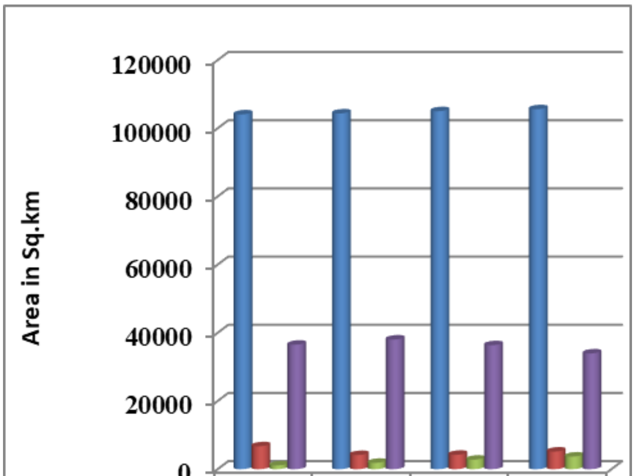
### 3.2. Spatio-temporal distribution of LST in Gedeo Zone between 2005 and 2022

The average LST in Agroforestry, Bare Land, Farm Land, and Built-up area has progressively increased over the years, from 19.6 $^0$C, 26$^0$C, 20.23$^0$C, and 25.58$^0$C in 2005 to 25$^0$C, 32.16$^0$C, 28.23$^0$C and 30.62 in 2022, respectively. The overall result revealed that the average LST in $^0$C has increased from 2005 to 2022.

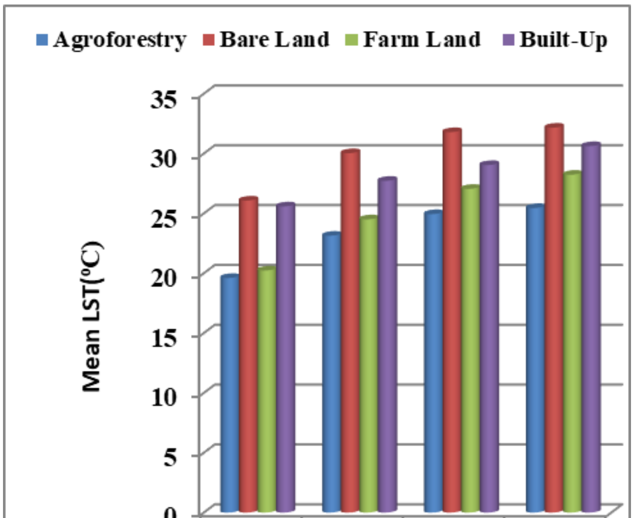
The maximum change in mean LST was observed between 2005 and 2011. Accordingly, the mean LST abruptly increased by 3.53$^0$C, 3.96$^0$C, 4.27$^0$C, and 2.14$^0$C in Agroforestry, Bare Land, Farm Land, and Built-up, respectively. On the other hand, the minimum mean LST change was detected from 2011- 2017 and 2017- 2022. In the last 17 years, the mean LST increased even though the coverage area of agroforestry increased; a slight analogous relationship was detected between LST and agroforestry area coverage.




| | 2005 | 2011 | 2017 | 2022 |
|---|---|---|---|---|
| Agroforestry | 104071 | 104347 | 105011 | 105591 |
| Bare Land | 6725.7 | 4163.13 | 4226.94 | 5169.78 |
| Built-up | 1092.6 | 1864.26 | 2801.61 | 3693.87 |
| Farm Land | 36515.7 | 38030.7 | 36364.9 | 33950.3 |




| | 2005 | 2011 | 2017 | 2022 |
|---|---|---|---|---|
| Agroforestry | 19.6 | 23.13 | 24.94 | 25.45 |
| Bare Land | 26.07 | 30.03 | 31.79 | 32.16 |
| Farm Land | 20.23 | 24.5 | 27.05 | 28.23 |
| Built-Up | 25.58 | 27.72 | 29.04 | 30.62 |

## 4. Discussion

An investigation of the dynamics of LULC across the Gedeo Zone revealed the increased need for land for urban expansion. Accordingly, the built-up area coverage has increased by 2601 km$^2$ from 2005 to 2022. Similar studies in Ethiopia revealed the need for land by the cities and towns due to urban expansion (Terfa, Chen, Liu, Zhang, & Niyogi, 2019). The coverage of Agroforestry has increased steadily by 1520 km$^2$ from 2005 to 2022. This indicates that agroforestry practices have been successful in maintaining and even expanding the forest cover while also providing for agricultural needs (Bishaw, 2001). This suggests that the Gedeo Zone is actively engaging in agroforestry practices to sustainably manage the land and maximize productivity(Shanka, 2022).

The overall analysis of the LST distribution result revealed that the mean LST in $^0$C has increased from 2005 to 2022. This could be due to various factors such as urbanization, changing agricultural practices, and land degradation (Tsegaye, 2019; Wassie, 2020). Even though the area coverage of Agroforestry increased, the dynamics of other LULC and other factors like global warming could play a vital role in the rise of average LST. Other factors like urbanization and global warming could play a significant role in changing LST locally as well as globally(Murray, Quam, & Wilder-Smith, 2013). Thus, the rise of LST may not be dependent on the local LULC change only.

The Northern areas including Dilla Town and its surrounding have experienced significant urbanization with a maximum recorded mean LST between 2002 and 2022. Understanding the impact of LULC on LST is important for identifying areas where agricultural productivity may be at risk(Parven et al., 2022). The Northwest and Southern parts of the study area; the area bounded by the West Guji zone has dominated by Bare Land and negatively influenced agricultural productivity(Kafy et al., 2021). These areas should be targeted for interventions such as irrigation and shade management. These interventions can help to mitigate the negative effects of high temperatures on agricultural productivity and ensure sustainable agricultural production in the region.

## 5. Conclusion

The overall dynamics of LULC in the study area indicated a gradual shift towards sustainable practices such as agroforestry, as well as urbanization and changes in agricultural practices. Policymakers need to monitor and manage these changes to ensure sustainable land use and minimize negative impacts on the environment and livelihoods. From the result of the study, the next conclusions were attained: The area coverage of the built-up area and bare land has increased rapidly while the coverage of agroforestry increased slightly from 2002 to 2022; leading to the rise of LST. The increased area coverage of agroforestry may not guarantee the cooling down of LST; other factors like urbanization and global warming could play a significant role in changing LST locally as well as globally.

## Acknowledgement

I would like to express my gratitude to Co-authors Mr. Gashaw Kibret, Mr. Sied Ali, and Mr. M Muhammed Rais. Their contributions were critical to the success of this research.

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