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RESEARCH

# Urbanization-induced land use/land cover change and its impact on surface temperature and heat fluxes over two major cities in Western Ethiopia

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**Abstract** Much of the urbanization that occurs in Africa creates the potential for technological development and economic growth but is also a breeding ground for environmental and health problems. This study was undertaken to evaluate the urban-induced land use/land cover (LULC) change and its contribution to the land surface temperature (LST) and urban heat fluxes from 2001 to 2021. More specifically, the study analyzed different scenarios of LULC change and retrieved the LST to evaluate the trends of the urban heat flux (UHI) in response to the urban-induced LULC change. The analysis of LULC change from 2001 to 2021 indicated that built-up and bare land showed the highest rate of increase at the expense of declining open spaces, agricultural land, and vegetation areas. The built-up areas in Nekemte and Jimma City increased by 929.25 ha (172.75%) and 2285.64 ha (226.93%) over the investigated period, respectively. The highest changes in LULC are seen in built-up areas followed by agricultural land, while the smallest changes are shown by water body followed by bare land. Built-up areas showed the highest net gain, while agricultural land experienced the greatest loss. In areas where the vegetation cover is low, low LST was depicted, and high LST was shown in areas where built-up areas were concentrated in both cities. Due to the LULC changes, the average LST increased by 1.9 °C and 2.2 °C in Nekemte and Jimma City, respectively, over the last 21 years. The urbanization-induced LULC change does not only cause changes in the hydrological process but also changes in the thermal variations and urban heat stress of the two urban centers. The result indicates that the increases in vegetation and green areas are significant in improving the heat stress and thermal characteristics of urban areas. Overall, to achieve sustainable urban development, the integration of land use with urban planning policies could be critical to the resilience of local environment and urban ecosystem.

**Keywords** Nekemte · NDBI · NDVI · UHI · Urbanization

## Introduction

With the intensification of several global and regional issues, population growth, urbanization, and climate change have become the most apparent environmental challenges (Dibaba et al., 2020a, b; Perry et al., 2022). More than half of the world's population lives in urban regions such as cities and towns, and much of the urbanization that would occur in Asia and Africa would cause significant social, economic, and environmental transformations but also problems

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(Guechi et al., 2021; Stemn & Kumi-Boateng, 2020). According to Oloke et al. (2021), urbanization creates the potential for economic growth and development in areas with good planning and sound resource management. Moreover, urban areas are not only the center of technological development and economic growth but also a breeding ground for environmental hazards, inequalities, and health problems (Kuddus et al., 2020). Particularly, the impacts are more prevalent in areas where cities have dense populations and inadequate urban infrastructure, and people who are situated near open sewers, and restricted areas such as riverbanks, and hillsides suffer greatly.

Associated with urbanization, population growth presents a significant opportunity for economic transformation from rural agriculture to diversified urban industrial and service sectors (World Bank Group, 2015). However, urbanization in most developing countries is a population growth driven by natural birth and rural–urban migration, and has not yet brought the prosperity that might be expected. In areas where services and infrastructures are inadequate and inefficient, major environmental and economic crises are common.

Urbanization problems in Africa are highly interconnected. Poor planning and land use policy, rapid changes in land use/land cover (LULC), inadequate infrastructure, and services such as lack of proper drainage systems, water supply, and solid and wastewater treatment are among the most common ones (Arsiso et al., 2018). LULC changes brought by urbanization cause the conversion of cropland, leading to losses in food production, and conversion of wetland and forest lands, leading to loss of ecosystem services which in turn causes an increase in health risks and environmental degradation. Moreover, LULC changes alter surface energy, changing land surface temperature (LST), causing changes in the region's climate, population, and environment (Stemn & Kumi-Boateng, 2020). With increases in built-up areas due to the LULC change, the increase in temperature and surface climate is becoming higher in urban environments than in areas covered by vegetation and water bodies. The largest issue with urbanization, according to Baram et al. (2021), is the growing temperature of the earth's surface, which is brought on by deforestation, a decline in green space, and an increase in solid surface. The changes have an adverse impact on the local and regional environments (Das et al., 2020). Furthermore, urban expansion leads to changes in watershed hydrology, including a decline in the natural filtering capacity of the river system due to the decline in floodplains and wetlands. Modifications of vegetation and soil through the development of urban infrastructure entail a substantial increase in the frequency and magnitude of storm runoff responses and urban flooding (Dibaba & Leta, 2019). Moreover, urbanization affects the timing and magnitude of precipitation in the urban watershed and increases the storm runoff responses to precipitation due to greater stormwater peaks generated by the impervious surfaces (O'Driscoll et al., 2010).

The impacts of urbanization are not only limited to LULC change; the increased commercialization and industry brought by urban growth also increase the use of fossil fuels which will add to global warming and contribute to climate change. Global warming combined with intensified urbanization process enhances warming in cities, especially during heat-related events including heat waves (IPCC, 2019). Climate change induced by industrialization and urbanization has witnessed tremendous activities that have had an impact on human livelihoods over the last two centuries (Oloke et al., 2021). According to the Intergovernmental Panel on Climate Change, heat waves are becoming more intense and frequent with severe environmental concerns emerging (IPCC, 2014). According to a study by Dessu et al. (2020) in southwest Ethiopia, the rapid expansion of built-up areas combined with the decline in vegetation cover has resulted in progressive changes in the local climate, especially surface temperature, and rainfall over the urban centers. The increase in surface temperature coupled with changes in rainfall patterns will intensify the extreme hydro-climatic events that can significantly affect city life. Therefore, the study on the complex relationship between urbanization-induced LULC changes and LST changes is imperative to understand the interaction between the factors and local climatology for proper spatial planning.

More recently, several studies have established the strong impacts of LULC change on surface temperature and reported that the relative rise in LST depends on LULC change (Das et al., 2020; Guechi et al., 2021). Land surface temperature is dependent on LULC patterns, according to Zhao et al. (2017), and it is well known that variations in LULC cause major changes in LST (Barbieri et al., 2018; Stemn &

Kumi-Boateng, 2020; Wang et al., 2021). This demonstrates that any anthropogenic activities that alter the LULC of a specific area pose a serious threat to LST changes in that location, and as a result of the rapid rate of global urbanization, LST studies continue to be significant and garner significant study attention. However, the process of rapid urbanization and its consequences on growth, particularly on the urban economy, are poorly understood in Ethiopia (Mezgebo, 2021). According to Dessu et al. (2020), urbanization alters the local climate, typically increasing surface air temperature and changing rainfall intensity and patterns. Degefu et al. (2021b) also reported that the amount, content, structure, and role of green space in urban areas have significantly changed as a result of urbanization and the tremendous landscape change that it has brought about. The degree of change, however, is dependent on the season, regional circulation, climate, geographic location, and features of the surrounding land cover. Moreover, the influence of geography, human activity, and climate on urban LST was still a topic of discussion, according to Wang et al. (2021). Contrarily, the main urbanization-related issues in developing nations like Ethiopia were linked to a rapid urbanization with unplanned expansions. Moreover, there is not enough information available regarding the spatial characteristics and implications for LULC of the cities' long-term growth as well as that of the nearby towns.

Despite the fact that several studies on land use and land cover have been undertaken in various regions of Ethiopia, few have sought to relate LULC and LST. The majority of studies are centered on the analysis of LULC change trajectories, causes, and environmental effects, as well as hydrology (Betru et al., 2019; Dibaba et al., 2020a; Miheretu & Yimer, 2017; Yesuph & Dagnew, 2019). The findings of the studies between LULC and the LST, however, have mostly concentrated on the linear relationship between the LST and some influencing factors, such as biophysical parameters (Degefu et al., 2021b).

Most of the Ethiopian cities experience high level of unemployment owing to the outpaces of the required level of economic and social development. According to Mezgebo (2021), urban areas are expanding fast in Ethiopia, but they are also plagued by a lack of essential infrastructures and public service, significant income inequality, growing informal sectors, and a housing crisis. Political decisions and policy were among the driving forces behind this expansion. In addition, recent study reports have demonstrated that informal settlements and urban informality have turned into widespread issues in Ethiopia's metropolitan areas (Abebe et al., 2019). For example, 34,438 informal houses were reported in Jimma in 2018. The rapid population growth, unemployment, and lack of proper infrastructure in rural areas and weak legal frameworks were the major factors for the informal settlements.

In order to prevent the current conditions from making cities unpleasant places to live, there is a critical need to prepare appropriate interventions for urban areas given the preponderance of rapid expansion in Ethiopian urban centers. However, in the majority of urban areas, practitioners and decision-makers have limited access to information and reliable datasets. Consequently, a compressive study that may aid in creating a baseline and drawing conclusions from empirical data to support future changes at the national and regional level is needed. Moreover, for predicting urban modeling and evaluating ecological changes and their local environmental effects, accurate knowledge on urban dynamics is crucial. For instance, Wang et al. (2021) reported that understanding the spatial distribution of LST and the factors influencing its pattern and advancement is essential for the development of sustainable urban plans.

In more recent years, the built-up area is highly increasing across all cities in Ethiopia and the western and southwestern region, in particular, due to the strategic location of the area and suitability of the region for socio-economic activities. Jimma City in the southwestern and Nekemte City in the western part of the country are among the fast-growing cities in Oromia Regional state, south and western parts of Ethiopia. Both cities are found at a strategic place owing to their central location with their dominant natural resource, coffee, and crop production. Besides their critical role in the country's socio-economic development, the rapid growth of the cities is challenging the region to think about how to meet the demands of the rapidly expanding urban population in the future. Moreover, the main issues with Nekemte City and Jimma City development are the failure to acknowledge environmental restrictions and limited attention to address population growth potential (Dibaba & Leta, 2019; Gobena, 2020). The two cities are among the urban centers in the country facing the challenges associated with a high level of imperviousness and flooding. According to Dibaba (2018), over exploration of natural resources added with poor land use planning and unplanned urban expansion have intensified urban flooding in Jimma City. However, the level of imperviousness contributing to urban flooding is not well documented in the areas to take design interventions. Moreover, the steep and hilly topography of the cities were subjected to a frequent flooding during the main rainy season. Lack of proper integration between road and urban storm water drainage due to the unplanned urban expansion has exposed the cities to flooding risks. A recent study in Nekemte elucidated the need to identify and map the extent of the built-up area in order to know the level of imperviousness that could contribute to urban flooding problems (Gobena, 2020).

Although there exist numerous studies on climate change across Ethiopia, less attention has been given to the study of urban climates in the past. The fundamental difficulty with the aforementioned issue is the lack of suitable data sets for analyzing climate data. For example, Jimma City has a single gauge station for temperature and precipitation. Moreover, the study on how urban heat islands respond to the urban-induced LULC change is very limited. In this respect, using remote sensing tools offers a great an opportunity to make analysis for the historical climate change analysis. Modeling how urban-induced LULC affects surface temperature is important to contextualize the implications of the urban expansion on climate change to advance and achieve sustained development of Nekemte and Jimma City. To extract the difference in LST from the LULC change, remote sensing, and geospatial technologies are widely used in recent research (Ayanlade & Howard, 2019; Debie et al., 2022; Degefu et al., 2023; Stemn & Kumi-Boateng, 2020). The use of remote sensing with GIS in monitoring the LULC dynamics and estimation of LST provides a wider range of measurements and good spatial consistency compared to the conventional observation methods used at meteorological stations (Guechi et al., 2021). This is an important input for urban planners, land use planning, and decision makers to see what options are good to manage the surface temperature in urban areas. Moreover, the relationship between urbanization-induced LULC and its impact on LST enables addressing regional and local environmental issues to outline appropriate planning for future development and for risk assessment.

Hence, the main objective of this study is to analyze the urbanization-induced LULC changes of Jimma City and Nekemte City, assess the spatio-temporal variation of land surface temperature, and calculate the urban heat islands using GIS and remote sensing applications.

## Materials and methods

### Description of the study area

Jimma City, the study area, is situated 352 km southwest of Addis Ababa, the capital city of Ethiopia. Geographically, the city is located at latitude 7.40° north and longitude 36.50° east (Fig. 1). It is positioned in the middle and connected to all parts of

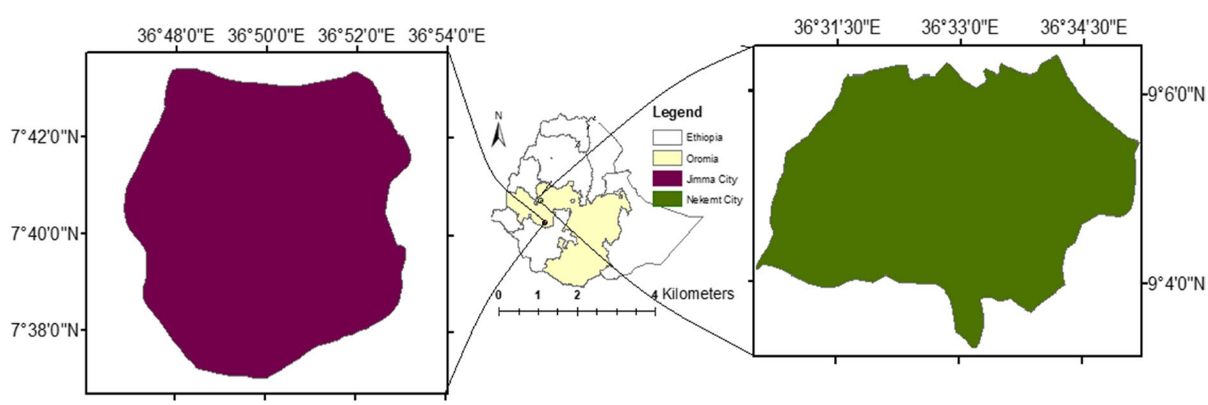


**Fig. 1** Map of the study area

the southwest region of Ethiopia in all directions. The northern part of Jimma City is situated on a rolling topography and the central portions of the city's southern section is found on an alluvial plain with a lower elevation. In the northern portion of the city, coffee is widely available, while in the southern section, there are eucalyptus and various tree plantations (Dibaba, 2018).

Nekemte City, the capital city of Eastern Wollega, is located in Western Oromia Regional State located at a latitude 9°5′N and longitude 36°33′E with an elevation of 2088 m 325 km west of Addis Ababa. The city is positioned in the center of the western region and is connected to three zones of Wollega in different directions. The slope of the entire Nekemte City is characterized as a combination of high, medium, and relatively flat slopes at the neighborhood level. There are steep slope areas along riversides and existing drainage lines that indicate erosion caused by the higher speed of stormwater runoff (Gobena, 2020).

Jimma City has area coverage of 105.7 $km^2$. Topographically, Jimma City is situated in the elevation ranges from 1684 m in the south east to 2289 m in the north east direction. Nekemte City, on the other hand, has a surface area of 29.5 $km^2$ and elevation range from 1978 m in the south to 2195 m in the east. Jimma City had a total population of 120,960 in 2007, whereas Nekemte City had a population of 76,817 in the same year, according to the Central Statistical Agency's 2007 report (CSA, 2007). In 2013, Jimma's population increased to 157,432, whereas Nekemte City's population increased to 105,358 (CSA, 2013).

Jimma and Nekemte City were chosen for this study owing to the fast rate of urbanization and informal settlements in the area. For example, however, there has been relatively little research done on these areas, and there is a dearth of data. Both cities share the same kinds of agro-ecologies and receive more rain throughout the year than most of Ethiopia's regions, which is one of their shared characteristics. Additionally, coffee and coffee processing enterprises, small scale enterprises, and mineral explorations are known to operate in the surrounding areas of both cities. Small scale enterprises include those that manufacture metal, wood and wood processing, manufacture brick, and process brick and construction material enterprises. However, Jimma City exhibits the highest pace of urban growth and has many small-scale enterprises involved in various forms of agro-processing than Nekemte City. Moreover, Jimma City is home to a large industrial park built to serve as an agro-processing hub for the south and west regions.

In the past 40 years, Jimma City has experienced an average annual rainfall of 1529 mm and temperatures that typically ranged from 13.8 to 30 °C, while Nekemte City received average annual rainfall of 1591 mm with temperatures that typically ranged from 13.1 to 25.5 °C over the past 34 years (Gemeda et al., 2021). The area's main cash crop is coffee, and it is evident that Jimma is a gift of coffee to Ethiopia and the rest of the globe. While maize, wheat, and teff are the dominant crops in the periphery of Nekemte City, maize and wheat were the dominant crops around Jimma City. Farmland, built-up, forest, open space, and water were the predominant LULC in Nekemte City (Gobena, 2020), while agricultural land, vegetation/forest land, bare land, wetland, and grass land were the key LULC cases in Jimma City (Abebe et al., 2019).

## Data collection and processing

### *Data sets*

Landsat images, digital elevation model (DEM), and field data were used in this study. One set of Landsat 7 ETM+ images (for the period of 2001) and one set of Landsat 8 OLI images (for the period of 2021) obtained from the US Geological Survey (USGS) (https://earthexplorer.usgs.gov) were used for the LULC change analysis (Table 1). To minimize the effects of a seasonal variation in vegetation pattern and distribution throughout a year, the selection of dates of the acquired images is made in the same annual season of the acquired years. Moreover, in order to reduce the impact of the cloud cover on

**Table 1** Landsat scenes, sources, and specifications used in this study

| Acquisition year | Satellite image | Spatial resolution | Used bands | Band number used for LST |
|---|---|---|---|---|
| 2001 | Landsat 7 ETM+ | 30 | 1–5,7 | 6 |
| 2021 | Landsat 8 OLI | 30 | 1–5,7 | 10 |

the analysis, the Landsat imagery was taken in the dry season. A 30 m×30 m resolution DEM obtained from USGS was used to characterize the elevation.

Field observation was carried out based on checklists designed in advance to observe the situation in both cities and to enrich the study. With the aid of field observation, information from experts, and a review of documents from national and regional offices, six nomenclatures of LULC types were identified as presented in Table 2. The six LULC nomenclatures used in this study are agricultural land, bare land, built-up, vegetation, open spaces, and water body. The selection of the LULC classes and nomenclatures was done based on previous studies in the study areas (Abebe et al., 2019) and similar studies in four cities of Ethiopia (Degefu et al., 2023) supported by field observations.

The combined geospatial technique, normalized difference vegetation index (NDVI), and normalized difference built-up index (NDBI) were used to prepare and derive the LULC maps and produce the LST maps. The procedures for Landsat Image classifications outlined by Dibaba et al. (2020a) were used in this study to prepare the LULC maps. Training data sets were employed to create LULC class signatures which are then used to categorize the entire image into meaningful information classes. The maximum likelihood technique in supervised classification was used for LULC classifications using ERDAS Imagine 2015. The reference data for image classification and accuracy assessments were collected through direct field observations using Global Positioning System (GPS) and high spatial resolution imagery available by Google Earth. To understand the current state of the cities and to gather ground truth information that was used to categorize the LULC map of the 2021 photos, fieldwork has been conducted in both cities using checklists that have been created in advance and with the assistance of field guides who are locals. To further understand the socioeconomic differences between the two cities and the historical and current situations of LULC, key informant interviews with important stakeholders from the two cities were conducted. Open-ended questions on the significant growths in built-up, infrastructures, demography, and socio-economic activities were prepared and used for the key informant interview. Information on natural resources and the population-environment nexus was obtained through discussions on land use planning practices, regulations, infrastructure, and urban planning initiatives and challenges.

Seventy percent of the reference data was used to create training for image classifications. Accuracy assessment was used to validate the accuracy of the classified maps using 30% of the reference data. A similar approach was used in different parts of the world (Degefu et al., 2023; Pulighe et al., 2015; Tadele et al., 2017). Overall classification accuracy and the kappa coefficient derived from the error matrix were used to determine the level of accuracy assessment. After creating the necessary accurate map, then, ArcGIS 10.3 was used to prepare the LULC maps of 2001 and 2021. The analysis of the LULC change was computed based on Eq. (1).

$$\text{LULC change } (\%) = \frac{(\text{Ar} - \text{Ap})}{\text{Ap}} * 100 \quad (1)$$

where Ar is an area of the recent LULC and Ap is the area of the earlier/preceding LULC.

**Table 2** Types of LULC and its description adopted from Abebe et al. (2019) and Degefu et al. (2023)

| LULC classes | Description |
|---|---|
| Agricultural land (AL) | Areas used for crop cultivation (both annual and perennials), fallow plots, scattered rural settlements, some pastures, and plantations around settlements. |
| Bare land (BL) | Rock query sites, bare soil, and soil disposal areas were considered here. |
| Vegetation (VG) | Areas occupied by plantation forests and urban green parks, mixed urban forests. Plantations of indigenous species of trees and exotic trees. |
| Built-up (BU) | Areas congested with buildings of artificial surfaces, residential, commercial, public installation, industrial, and road and transportation infrastructures. |
| Open spaces (OS) | Area covered with small grasses, scattered bushes, and shrubs, mixed range lands, recreational sites, wetlands (permanent and intermittent) |
| Water body (WB) | Areas that are completely inundated by water like rivers, lakes, and man-made ponds. |

The LULC matrix was created in ArcGIS 10.3 to determine the trajectory of the LULC classes between 2001 and 2021. The matrix also helps to analyze the LULC inter-category transitions and determine areas of gain, losses, and persistence between the LULC classes.

*Land surface temperature derivations and processing*

LST maps were retrieved from the thermal infrared band 6 of Landsat 7 and band 10 of Landsat 8 with the help of mathematical models. The overall procedures used to develop the LST from the Landsat images described in Barbieri et al. (2018), Stemn and Kumi-Boateng (2020), Degefu et al. (2021a), and Guechi et al. (2021) are used in this study. Accordingly, four major steps are used to retrieve the LST for the two cities using the Landsat 7 ETM+ images for 2001 and Landsat 8 OLI TIRS for 2021. The procedures are described as follows:

**Step 1:** Converting raw digital numbers into top-of-atmosphere (TOA) radiance using Eq. (2) for ETM+ images and Eq. (3) for OLI (Barbieri et al., 2018; Das et al., 2020).

$$L\lambda = \frac{LMAX_\lambda - LMIN_\lambda}{Qcal_{MAX} - Qcal_{MIN}} * \left(Qcal - Qcal_{MIN}\right) + LMIN_\lambda \tag{2}$$

$$L\lambda = M_L * Qcal + A_L \tag{3}$$

where $L\lambda$ is spectral radiance, $LMAX_\lambda$ and $LMIN_\lambda$ are the maximum and minimum spectral radiances, $Qcal_{MAX}$ and $Qcal_{MIN}$ are the maximum and minimum pixel values, Qcal is the digital number (DN), and $M_L$ and $A_L$ are the band-specific multiplicative and additive rescaling factors from the image metadata.

**Step 2:** Converting TOA radiance to at-sensor brightness temperature using Eq. (4) for both ETM+ and OLI images (Das et al., 2020; Degefu et al., 2021b; Stemn & Kumi-Boateng, 2020).

$$T_B = \left( \frac{K_2}{ln\left(\frac{K_1}{L_\lambda} + 1\right)} \right) - 273.15 \tag{4}$$

where $T_B$ is at-brightness temperature in degree centigrade, $L_\lambda$ is TOA radiance, and $K_2$ and $K_1$ are band-specific thermal conversion constants from image metadata.

**Step 3:** Calculating the land surface emissivity ($\varepsilon$). As both cities are heterogeneous, the effect of emissivity ($\varepsilon$) should be considered in computing the LST. In this regard, the land surface emissivity $\varepsilon$ is calculated using Eq. (5) (Debie et al., 2022; Guechi et al., 2021).

$$\varepsilon = 0.004 * PV + 0.986 \tag{5}$$

PV is the proportion of vegetation calculated from NDVI using Eq. (6) (Guechi et al., 2021).

$$PV = \left[\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right]^2 \tag{6}$$

NDVI, which is derived from the near-infrared and red bands (band 4 and band 3 for ETM+ images and band 5 and band 4 for OLI images), is used to describe the condition of vegetative surface cover. Accordingly, NDVI is calculated using Eq. (7) (Ayanlade & Howard, 2019).

$$NDVI = \frac{NIR_{Band} - RED_{Band}}{NIR_{Band} + RED_{Band}} \tag{7}$$

**Step 4:** Estimating the LST from the at-sensor brightness temperature using Eq. (8) (Das et al., 2020; Degefu et al., 2023).

$$LST = \frac{T_B}{\left[1 + \left(\lambda * \frac{T_B}{\alpha}\right) ln\varepsilon\right]} \tag{8}$$

where $T_B$ is the $\alpha = hc/b$ (438 * $10^{-2}$ mk); $b$ is Boltzman's constant (1.38 * $10^{-23}$ J/K); $h$ refers to Planck's constant (6.626 * $10^{-34}$JS); $C$ is the velocity of light (2.998 * $10^8$ m/s), and $\varepsilon$ is the surface emissivity.

In order to analyze the impact of remote sensing indexes on the LST dynamics, NDVI and NDBI were derived from surface reflectance to describe the dynamics of urban ecosystems (Degefu et al., 2021b, 2023). The NDBI is computed to identify the proportion of built-up surfaces from the SWIR1 and near-infrared band (band 5 and band 4 for Landsat 7 and band 6 and band 5 for Landsat 8) using Eq. (9) (Degefu et al., 2023).

$$NDBI = \frac{SWIR_{Band} - NIR_{Band}}{SWIR_{Band} + NIR_{Band}} \quad (9)$$

where SWIR is the short-wave infrared band and NIR is the near infrared band.

*Urban heat island (UHI) derivations*

Once the LST was retrieved from the satellite datasets, normalizing the LST was performed following Degefu et al. (2023) and Halder et al. (2022) to evaluate the urban thermal balance. For proper urban planning and management, monitoring the heat stress and thermal variations in urban areas will be achieved through urban heat island (UHI) assessment (Halder et al., 2021, 2022). The UHI over the two cities is calculated using Eq. (10).

$$UHI = \frac{T_s - T_{mesn}}{SD} \quad (10)$$

where Ts is the LST map, Tmean is the mean LST, and SD is the standard deviation.

## Result and discussion

### Classification accuracy and LULC change analysis

The Landsat data from Landsat 7 (ETM+) and Landsat 8 OLI were used to prepare the LULC maps of 2001 and 2021, respectively. Both maps were validated using ground truth data with the help of accuracy assessments. Overall classification accuracy and kappa coefficients were used to assess the accuracy of the maps. The results of the overall accuracy assessment showed that the overall kappa coefficient varies from 0.85 to 0.91 and 0.89 to 0.93 with overall classification accuracy varying between 0.84 and 0.89, and 0.87 and 0.92 for Nekemte and Jimma City, respectively (Table 3). The result shows that the LULC maps were sufficiently accurate for use in further analysis. The overall kappa indexes and accuracy result shows strong agreement and acceptable LULC map accuracy for the analysis of LULC changes (Degefu et al., 2021a; Tadele et al., 2017; Viera & Garrett, 2005). According to Halder et al. (2021), the strength of agreement between 0.81 and 1 shows a very good agreement.

**Table 3** LULC classification accuracy assessments

| | | Nekemte | | Jimma | |
|---|---|---|---|---|---|
| | Landsat type | 2021 | 2001 | 2021 | 2001 |
| Overall classification accuracy | Landsat 7 ETM+ | 89.3 | 84.4 | 92.1 | 87.3 |
| Overall kappa coefficient | Landsat 8 OLI | 91.2 | 85.1 | 93.4 | 89.4 |

The study from the ground truth data and classified Landsat images of 2001 and 2021 revealed that both Nekemte and Jimma Cities have undergone numerous LULC changes over time. Based on the LULC 2001 analysis, agricultural land (41.5%) is the dominant LULC class followed by vegetation cover areas (22.7%) in Nekemte City, whereas agricultural land (40.7%) followed by open space areas (26.4%) are the dominant LULC classes in Jimma City. The proportion of built-up area was 18.4% in Nekemte and 9.5% in Jimma city in 2001. In 2021, built-up area covers the largest share (49.7%) of the total area followed by vegetation cover (20.6%) in Nekemte and built-up areas (31.2%) followed by agricultural land (30.5%) cover the largest portion in Jimma City (Table 4).

The spatial distribution of the LULC maps was shown in Fig. 2. According to the map, the built-up area has shown expansion in all directions. However, the main expansion of built-up areas was along the main road crossing the city in Nekemte, whereas it is from the central to the southern, eastern, southeastern, and northeast directions in Jimma City.

During the 2001–2021 period, the major increase was shown by built-up followed by bare land in both cities. On the other hand, agricultural land followed by open space area has shown a major decline in Nekemte City, whereas open space area followed by agricultural land has shown a major decline in Jimma City. Overall, a large percentage of changes were observed in the LULC classes that have shown an increment (built-up and bare land) than those which depicted declining (open space area and agricultural land) in both cities. Field observation result shows that the increase in bare land was mainly attributed by the increasing quarry sites and soil loss areas within the periphery of the cities. The increasing rate of built-up areas could be attributed to the highly increasing population,

**Table 4** The land use/land cover map of Nekemte and Jimma City

| | LULC class | Area | | | | Change (gain/loss) | |
|---|---|---|---|---|---|---|---|
| | | 2001 | | 2021 | | 2001–2021 | |
| | | ha | % | ha | % | ha | % |
| Nekemte | AL | 1225.3 | 41.5 | 582.2 | 19.7 | −643.1 | −52.5 |
| | VG | 668.4 | 22.7 | 608.1 | 20.6 | −60.3 | −9.0 |
| | OS | 481.0 | 16.3 | 243.0 | 8.2 | −238.0 | −49.5 |
| | BU | 541.3 | 18.4 | 1467.0 | 49.7 | 925.7 | 171.0 |
| | WT | 7.6 | 0.3 | 7.4 | 0.3 | −0.2 | −2.4 |
| | BL | 25.9 | 0.9 | 41.6 | 1.4 | 15.7 | 60.4 |
| | Total | 2949.5 | 100.0 | 2949.3 | 100.0 | | |
| | LULC class | Area | | | | Change (Gain/Loss) | |
| | | 2001 | | 2021 | | 2001–2021 | |
| | | ha | % | ha | % | ha | % |
| Jimma | AL | 4301.0 | 40.7 | 3226.3 | 30.5 | −1074.7 | −25.0 |
| | VG | 2345.7 | 22.2 | 2153.8 | 20.4 | −191.9 | −8.2 |
| | OS | 2788.9 | 26.4 | 1722.3 | 16.3 | −1066.6 | −38.2 |
| | BU | 1008.8 | 9.5 | 3300.3 | 31.2 | 2291.5 | 227.2 |
| | WT | 74.7 | 0.7 | 62.1 | 0.6 | −12.6 | −16.8 |
| | BRL | 46.4 | 0.4 | 100.5 | 1.0 | 54.1 | 116.6 |
| | Total | 10,565.5 | 100 | 10,565.3 | 100 | | |

Negative in the table shows a decreasing change/trend of the LULC type

migration to urban areas, and the associated infrastructures and construction of institutions in the cities. This could be associated with the encroachment of human activities and urbanization as it was indicated by similar studies (Degife et al., 2019). From the analysis, built-up areas in Jimma City have increased from 9.5% (2001) to 31.2% (2021) with the highest rate of increments (227.2%) and increased from 18.4% (2001) to 49.7% (2021) increasing by 171%. The result shows the rate of built-up expansions in Jimma City is higher than in Nekemte City. Expansion of institutes like establishments of Jimma Institute of Technology, Collage of Business and Economics and airport expansion, and developments of industrial parks and related infrastructures have attributed to the high expansion of built-up in Jimma City. Moreover, Jimma City have more population than Nekemte City. On the other hand, the need to have housing and infrastructures has contributed to extra pressure on the natural resources through the conversion of agricultural lands, open spaces, and vegetation covered areas in both cities. Similar causes have been reported in Gedeo area where there is a high record of population densities (Temesgen et al., 2018). The high and rapid rate of urbanization in both cities also confirms the study result by Degefu et al. (2023) who reported very rapid urbanization in the major cities of Ethiopia.

Agricultural land has shown a declining trend with the highest decline reported in Nekemte City (52.2%) than in Jimma (25%). Moreover, open space areas have shown a decreasing trend at a rate of 49.5% in Nekemte and 38.2% in Jimma City. The main causes of the agricultural land decline are an expansion of the built-ups. An increase in the price of land in urban areas has also caused the farmers to use a portion of their land for building houses and renting lands for others. Thus, the areas that can be used for agriculture are getting diminished. Consequently, the need to cultivate more land has not been limited to deforestation only but also draining the swamp areas and wetlands for farming and building houses. This could in turn have resulted in a decreased open space area.

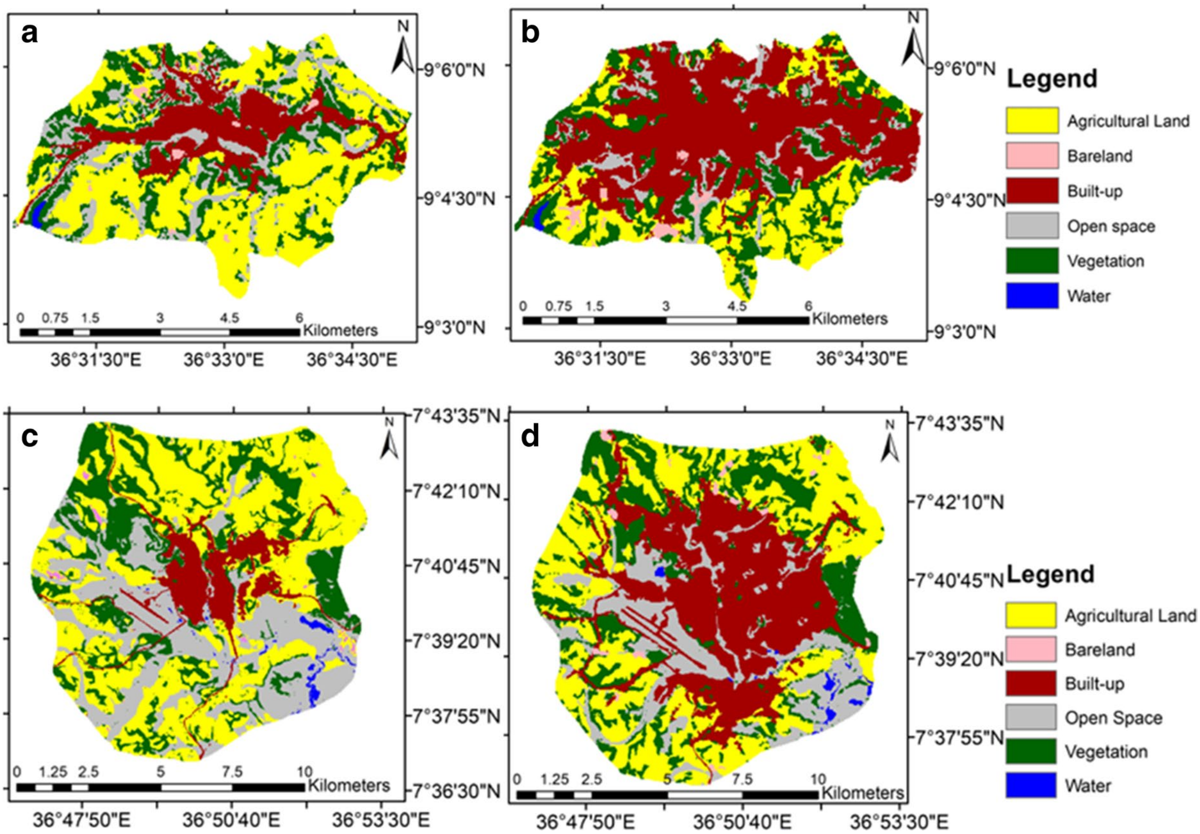


**Fig. 2** Spatial distribution of LULC for Nekemte City in 2001 (**a**) and in 2021 (**b**) and Jimma city in 2001 (**c**) and 2021 (**d**)

Field observation and ground truth data revealed that the conversions of the swamp areas to agricultural lands and built-up have caused a reduction in water yields in Jimma City. In addition to their limited existence, unlimited human activities and the decline of wetlands are imposing pressure on the resources. The needs to use water for domestic, car wash, and irrigation to improve societal activities are increasing from time to time. As a result, the coverages of natural flows in Awetu and Kito River crossing through Jimma City are getting diminished. Moreover, built-up areas have increased different effluents to the freshwater resources and unlimited waste disposal along the river banks caused water resource pollution and decreased availability of water.

Vegetation cover has shown a decreasing trend by 9% and 8.2% in Nekemte and Jimma City, respectively, over the analysis period. The decrease in vegetation cover could be brought due to the cutting of forests for the increased need of an agricultural land and the need of built-up expansions. Timber and other wood works are also found to be the main causes for deforestation.

The findings of a decrease in agricultural land and open space, and a significant increase in built-up areas reported in both cities are consistent with previous studies as documented by Abebe et al. (2019) which reported illegal settlements have caused an increase in built-up. However, the declining trend of the vegetation cover in Jimma City contradicts the increasing trends of vegetation cover as reported in Abebe et al. (2019). In the current state of vegetation cover in Jimma City, vegetation covers are actually not increasing. In this regard, the increasing report of vegetation cover by the previous study could be associated with the type of image classification and the accuracy of the maps used. Similar trends of unceasingly increasing built-up areas were also reported in Addis Ababa, Adama, Hawassa, and Bahir Dar cities (Degefu et al., 2021a). However, the rate of increase varies with the methods applied and the areal extent of the cities. Overall, the highest rate of increments was shown by built-up and bare land as reported by similar studies in Hawassa watershed (Degife et al., 2019). This has an adverse impact on natural resources like wetlands, vegetation, and water bodies. Similar trends of increasing built-up and reduction in agricultural land and forest areas with similar procedure were also reported in Guelma City, Algeria (Guechi et al., 2021). Khan et al. (2022) reported increasing built-up and bare land at the expense of declining vegetation in Mardan and Charsadda districts of Pakistan. On the contrary, the increase in urban agriculture was reported in Adama City, Ethiopia (Degefu et al., 2021a).

### LULC change trajectories

In order to better understand the LULC transitions and determine the areas gained, lost, persistence, and net change, the LULC matrix was developed for the 2001–2021 transitions. This will allow to understand how much area of LULC change is taking place for each type of LULC class for the past 21 years (Table 5). From the 1224.7 ha of agricultural land, only 410 ha of land remained as agricultural land in 2021 with 444.5 ha and 240.5 ha converted to built-up and vegetation areas, respectively, in Nekemte City. Likewise, from open spaces, only 70.3 ha of the area remained in the same class with the highest area (220.5 ha) converted to a built-up followed by a vegetation area (102.3 ha). Coming to Jimma City, 2190.6 ha of land remained as agricultural land in

**Table 5** LULC change matrix

| Nekemte LULC class | | 2021 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | AL | BL | BU | OS | VG | WB | Total |
| 2001 | AL | **410** | 30.7 | 444.5 | 99 | 240.5 | 0 | 1224.7 |
| | BL | 3.1 | **3.7** | 12.1 | 6.4 | 0.7 | 0 | 26 |
| | BU | 1.3 | 0.4 | **510.3** | 19.7 | 9.6 | 0 | 541.3 |
| | OS | 85.3 | 2.5 | 220.5 | **70.3** | 102.3 | 0.1 | 481 |
| | VG | 82.3 | 4.3 | 279.3 | 47.6 | **253.7** | 1 | 668.2 |
| | WB | 0 | 0 | 0 | 0 | 1.2 | **6.3** | 7.5 |
| | Total | 582 | 41.6 | 1466.8 | 242.9 | 607.9 | 7.4 | **2948.6** |
| | Gains | 172.0 | 37.9 | 956.5 | 172.6 | 354.2 | 1.1 | |
| | Loss | 814.7 | 22.3 | 31 | 410.7 | 414.5 | 1.2 | |
| | Net change | −642.7 | 15.6 | 925.5 | −238.1 | −60.3 | −0.1 | |
| | Net persistence | −1.6 | 4.2 | 1.8 | −3.4 | −0.2 | 0.0 | |
| Jimma LULC class | | 2021 | | | | | | |
| | | AL | BL | BU | OS | VG | WB | Total |
| 2001 | AL | **2190.6** | 45 | 1270.9 | 177.3 | 614.9 | 1.8 | 4300.5 |
| | BL | 32.3 | **1.5** | 6.2 | 3.1 | 3.3 | 0 | 46.4 |
| | BU | 9.4 | 0.8 | **905.8** | 79 | 13.8 | 0 | 1008.8 |
| | OS | 541.1 | 24.8 | 676.2 | **1279.4** | 224 | 43.2 | 2788.7 |
| | VG | 451.5 | 28.3 | 439.6 | 128.5 | **1295.7** | 1.8 | 2345.4 |
| | WB | 1.2 | 0 | 1.6 | 54.8 | 1.8 | **15.3** | 74.7 |
| | Total | 3226 | 100.5 | 3300.3 | 1722.1 | 2153.5 | 62.1 | **10,564.5** |
| | Gains | 1035.4 | 99.0 | 2394.5 | 442.7 | 857.8 | 46.8 | |
| | Loss | 2109.9 | 44.9 | 103 | 1509.3 | 1049.7 | 59.4 | |
| | Net change | −1074.5 | 54.1 | 2291.5 | −1066.6 | −191.9 | −12.6 | |
| | Net persistence | −0.5 | 36.1 | 2.5 | −0.8 | −0.1 | −0.8 | |

The diagonals written in bold shows area of land that did not change between 2001 and 2021

2021. Overall, agricultural land has shown the highest loss of land from 2001 to 2021 in both cities, while the highest gain was shown by built-up areas. The portion of vegetation changed to agricultural land was higher than the vegetation changed to built-up in Jimma City. However, area of land converted to agriculture is lower than to built-up in Nekemte City. On the other hand, the portion of open space area converted to agriculture was lower than the area of open space converted to built-up in both cities.

The highest loss of lands was shown by the agricultural lands followed by vegetation and open space areas in Nekemte City, whereas agricultural land followed by open space and vegetation areas has shown the highest loss in Jimma City. In both cities the lowest loss occurred for water body and bareland. On the other hand, the highest gain occurred in built-up followed by vegetation in Nekemte City, whereas built-up followed by agricultural land has shown the highest land gain in Jimma City. The LULC classes that have shown the highest gain are those accounting the largest part of the urban areas.

In Nekemte City, the least persistent LULC class was bareland, whereas water body was the most persistent LULC class. The net change in persistence ratio was large for bareland (positive) followed by open space (negative). The highest net change in persistence ratio was experienced by bareland followed by built-up areas in Jimma City. Besides, the most persistent LULC class was vegetation cover and bareland was the least persistent LULC class. The findings of this study are in line with most of the LULC change reports in Ethiopia (Arsiso et al., 2018; Degife et al., 2019; Dessu et al., 2020; Yesuph & Dagnew, 2019) who reported a continuous expansion of urban areas at the expense of natural vegetation.

## LULC change implications

Studies show that LULC changes have direct implications on the hydrological process, water quantity, and quality. The increase in non-vegetative LULC changes results in an increasing trend of runoff, flood vulnerability, changing river morphology, and sedimentations. The removal of vegetation and intensive agriculture on steep slopes exposes the land to the impacts of raindrops and severe soil erosion problems. Areas of land with low vegetation cover are subject to higher surface runoff and low infiltration (Dibaba & Ebsa, 2022). Especially, the decline in wetlands and the increase in surface runoff and urban flooding due to the increasing built-up areas are big problems for areas like Jimma City due to its central location and proximity to the Gilgel-Gibe I reservoir. Likewise, in areas like Nekemte where the topography of the city is highly complex, the increase in imperviousness due to the increase in built-up could result in damaging urban floods. Moreover, in areas where the surrounding areas have experienced similar dynamic LULC change, the drying-up of lakes was reported by Assen (2011) in lake Haramaya. This urges proper land use planning for Jimma City owing to its strategic location with respect to nearby lakes (Awetu pond and Gilgel Gibe I Reservoir). Although developments are necessary to fulfill basic needs, any activity should take into account the health and sustainability of the environment. Especially, encouraging the community to adopt different agro-forestry in the upstream areas of Jimma City and restricting uncontrolled activities along Awetu and Kito Rivers have paramount environmental, social, and economic benefits. Moreover, conserving the wetlands and the river banks helps to preserve their immense ecosystem services.

The increase in built-up areas in developing nations where cities have dense populations and inadequate urban infrastructure is a central cause for various socio-economic and environmental problems. As shown by the LULC change analysis, the expansion of built-up areas at the expense of open space declined in both cities. Previous studies on the assessment of the impacts of urban expansion on LULC changes also documented significant increases in built-up areas and declines in open space and vegetation cover in Addis Ababa (Arsiso et al., 2017). According to Arsiso et al. (2017), urbanization, coupled with population growth and climate change, will result in water scarcity in the city.

## Spatiotemporal distributions of LST

The spatial distribution of LST in both cities has shown a varying magnitude of LST value with respect to the LULC classes. However, similar associations with the LULC classes are observed (Fig. 3). In both cities, built-up areas have higher LST. However, it is not only the built-ups that contributed to the surface temperature rise but also anthropogenic activities that

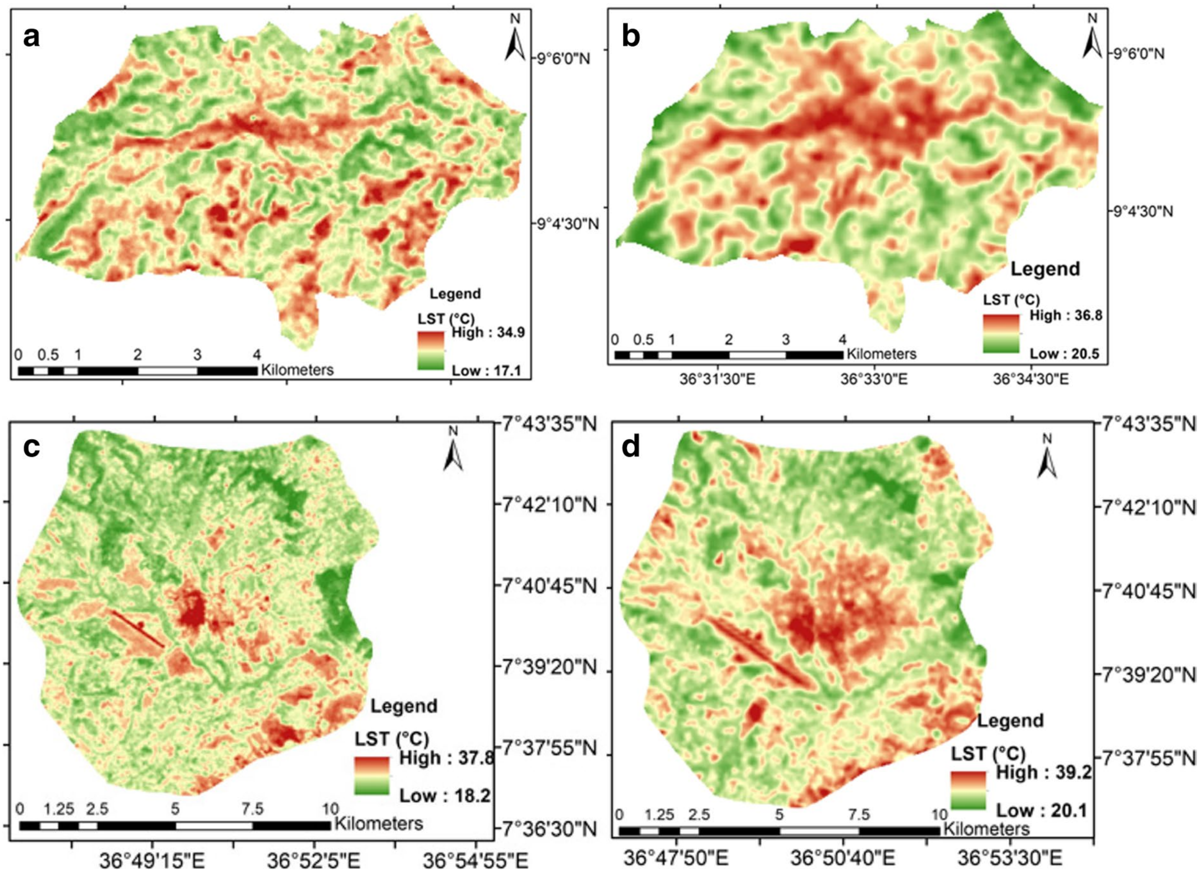


**Fig. 3** LST map of Nekemte City in 2001 (**a**) and in 2021 (**b**) and Jimma city in 2001 (**c**) and 2021 (**d**)

transform the surface cover. Higher LST was associated with built-up areas, dry lands of open space, and bare land compared to other land cover classes in 2001 for both cities. In 2021, however, LST has significantly changed. Higher LST values are reported from impervious surfaces and built-ups. In both years, low LST was associated with areas having good vegetation cover and water bodies. This finding was consistent with previous studies in different areas. Stemn and Kumi-Boateng (2020) in Ghana and Barbieri et al. (2018) in Italy reported that surface temperature is highly associated with vegetation cover conditions. Low surface temperature is associated with high vegetation cover and vice versa.

Through time, LST is increasing in both cities, but with varying magnitude. In Nekemte City, the maximum LST is 34.9 °C with a minimum LST of 17.1 °C and an average LST of 24.68 °C in 2001. In 2021, the maximum LST and minimum LST have increased to 36.8 °C and 20.5 °C, respectively, with an average LST of 26.65 °C. Likewise, maximum LST has increased from 37.8 to 39.2 °C and minimum LST have increased from 18.2 to 20.1 °C with an average LST increased from 25.6 to 27.8 °C in Jimma City. The maximum LST has increased by 1.9 °C (1.4 °C) and the minimum LST increased by 3.4 °C (1.9 °C) in Nekemte and Jimma City, respectively. Overall, the average LST has increased by 1.97 °C and 2.2 °C in Nekemte and Jimma City, respectively, over the past 21 years. In both cities, the LST is higher in central areas than in the outskirts. The LST analysis, however, shows Jimma City has a higher LST value than Nekemte City.

## LST vs LULC change

To understand the impacts of the LULC change on LST, the relationship between LULC classes and LST was assessed from 2001 to 2021 for both cities.

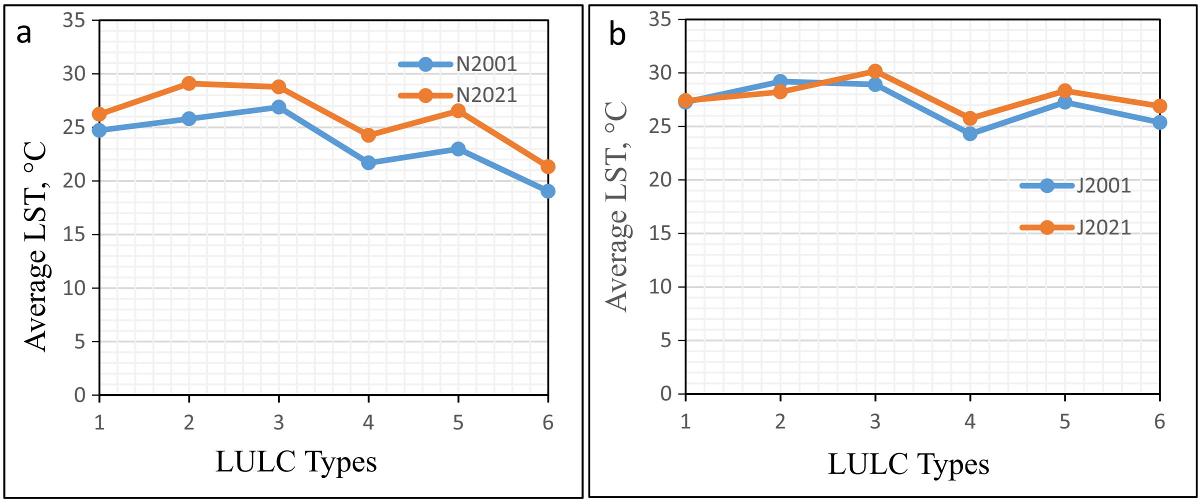


**Fig. 4** Temporal changes in LST in different LULC classes for Nekemte City (**a**) and Jimma City (**b**)

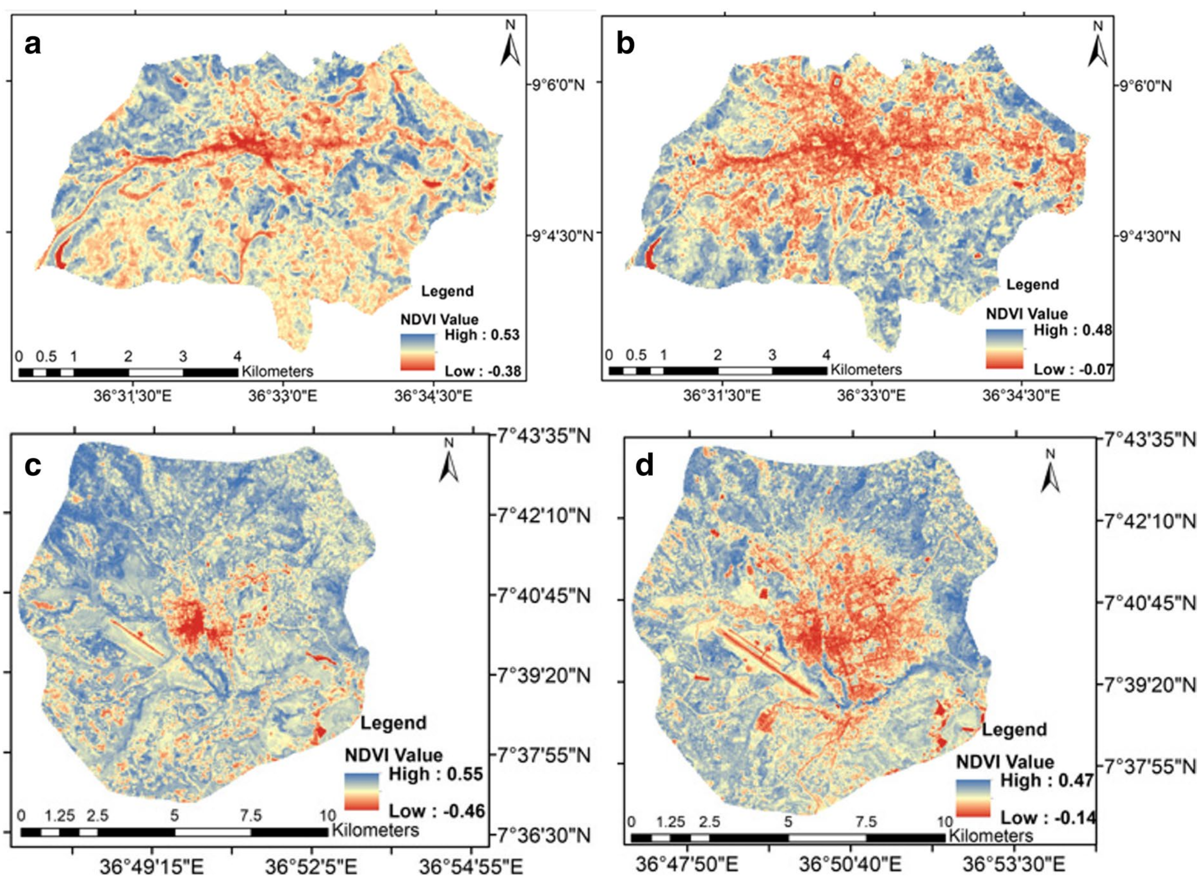


**Fig. 5** spatial distribution of NDVI for Nekemte City in 2001 (**a**) and 2021 (**b**) and Jimma City in 2001 (**a**) and 2021 (**b**)

Accordingly, each LULC class has shown a direct relationship with LST but a varying magnitude of LST through time (Figs. 4a and 6b). In 2001, the highest average LST was experienced by bare land (25.8 °C), followed by built-up (24.89 °C) and agricultural land (24.62 °C) in Nekemte City throughout the study periods considered. On the other hand, the lowest LST is associated with water body (19.04 °C) followed by vegetation (21.68 °C) and open space (22.98 °C) in Nekemte City. In 2021, all LULC classes have shown an increasing LST with the highest increase by built-up (3.88 °C) as presented in Fig. 4a. In Jimma, the lowest average LST is associated with vegetation, and the highest is associated with bare land in 2001. In 2021, however, the highest LST was from built-up areas. This result was consistent with the study report in different parts of Ethiopia (Degefu et al., 2021b). Degefu et al. (2021b) reported higher LST for built-up, urban agriculture, and bare land than vegetation and water. Area of land with no vegetation cover revealed higher LST than the shrubland, grassland, forest cover, and wetlands in northwest Ethiopia (Debie et al., 2022). The highest LST from bare land is also reported over Dire Dawa City, Ethiopia (Haylemariyam, 2018). Likewise, Zhao et al., (2017) in Shenyang, China, reported lower LST from river and lakes followed by vegetation, revealing the cooling effects of water and vegetation on thermal environments. Pal and Ziaul (2017) in English Bazar Municipality also reported the lowest LST from water bodies and the highest LST from impervious areas. In general, the sensitivity of the LST to urban-induced LULC changes confirms the inverse relationship between LST and water body and vegetation areas.

## Relationship between LST, NDVI, and NDBI

In both cities, rural areas have a higher NDVI value than urban areas. In Nekemte City, the NDVI ranged between 0.53 to −0.38 and 0.48 to −0.07 in 2001

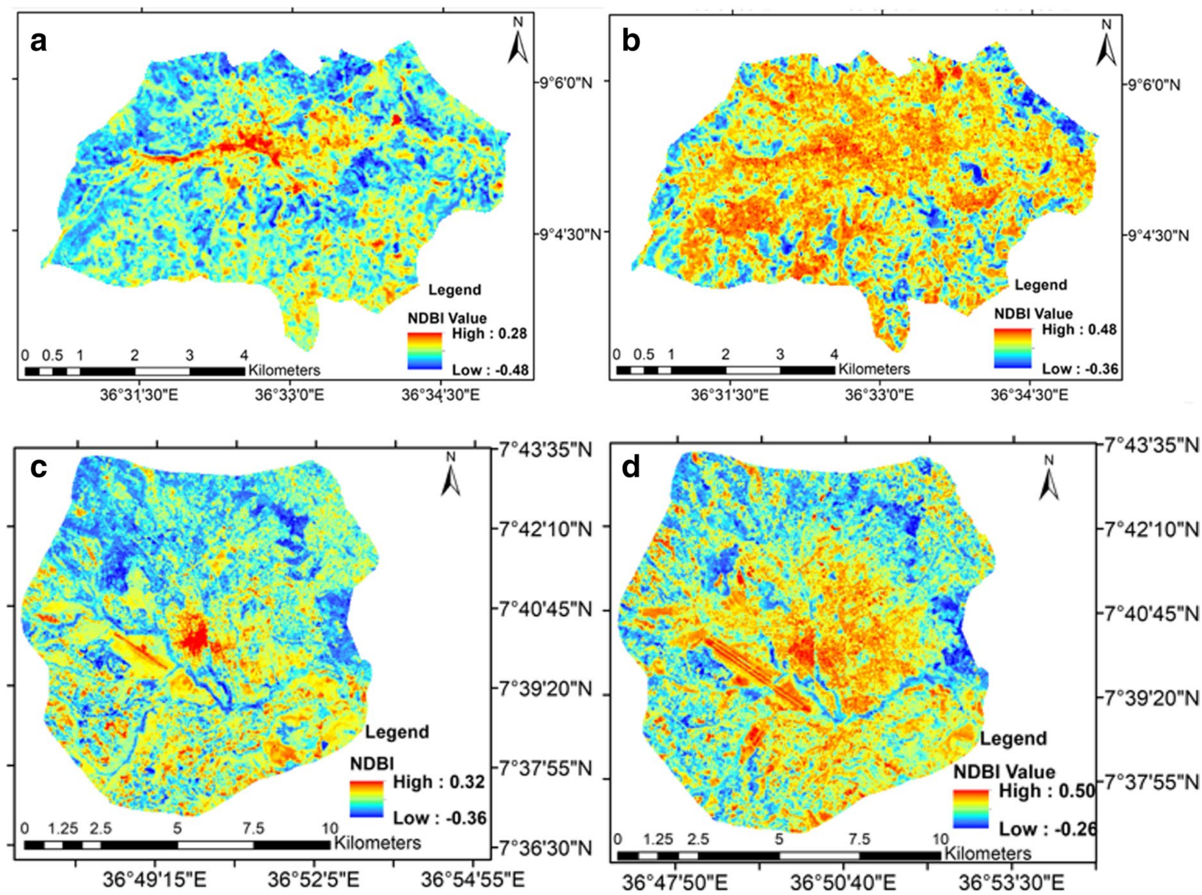


**Fig. 6** spatial distribution of NDBI for Nekemte City in 2001 (**a**) and 2021 (**b**) and Jimma City in 2001 (**a**) and 2021 (**b**)

and 2021, respectively (Fig. 5a and b). Likewise, the NDVI ranged between 0.55 to −0.46 and 0.47 to −0.14 in 2001 and 2021, respectively (Fig. 5c and d). In both cases, the spatial variation of the NDVI reveals low NDVI values for the water body and built-up areas and high NDVI values signifying a high density of vegetation. In Nekemte City, although the increase in the impervious surface and built-up has contributed to the increasing LST, other factors like bio-physical characteristics will also affect LST variations. For example, higher LST was reported in the southern part of Nekemte City from areas that were not built-up in 2001. In 2021, however, the majority of these areas are used for crop cultivation, and some of these areas are converted to vegetation through a plantation of eucalyptus trees. Consequently, the agricultural/open areas with high LST in 2001 have shown a medium LST in 2021 in areas where vegetation cover has increased. This finding is consistent with the study by Guechi et al. (2021) who reported that LST changes are highly related to the changes in LULC.

The association of NDVI with the LULC classes in both cities is consistent with previous studies (Barbieri et al., 2018; Stemn & Kumi-Boateng, 2020) that reported the presence of artificial impervious surfaces in areas with low NDVI values and high NDVI values indicating a high density of vegetation. Areas with low NDVI values reveal higher LST, and lower LST were associated with areas having higher NDVI. This means that vegetation areas that have higher NDVI value reveal lower LST and built-up areas with lower NDVI are associated with higher LST. This indicates green areas can help to contribute to reduce the LST and the associated UHI which is important for climate mitigation. In both cities, NDVI has increased for water body from 2001 to 2021, owing to water quality degradations.

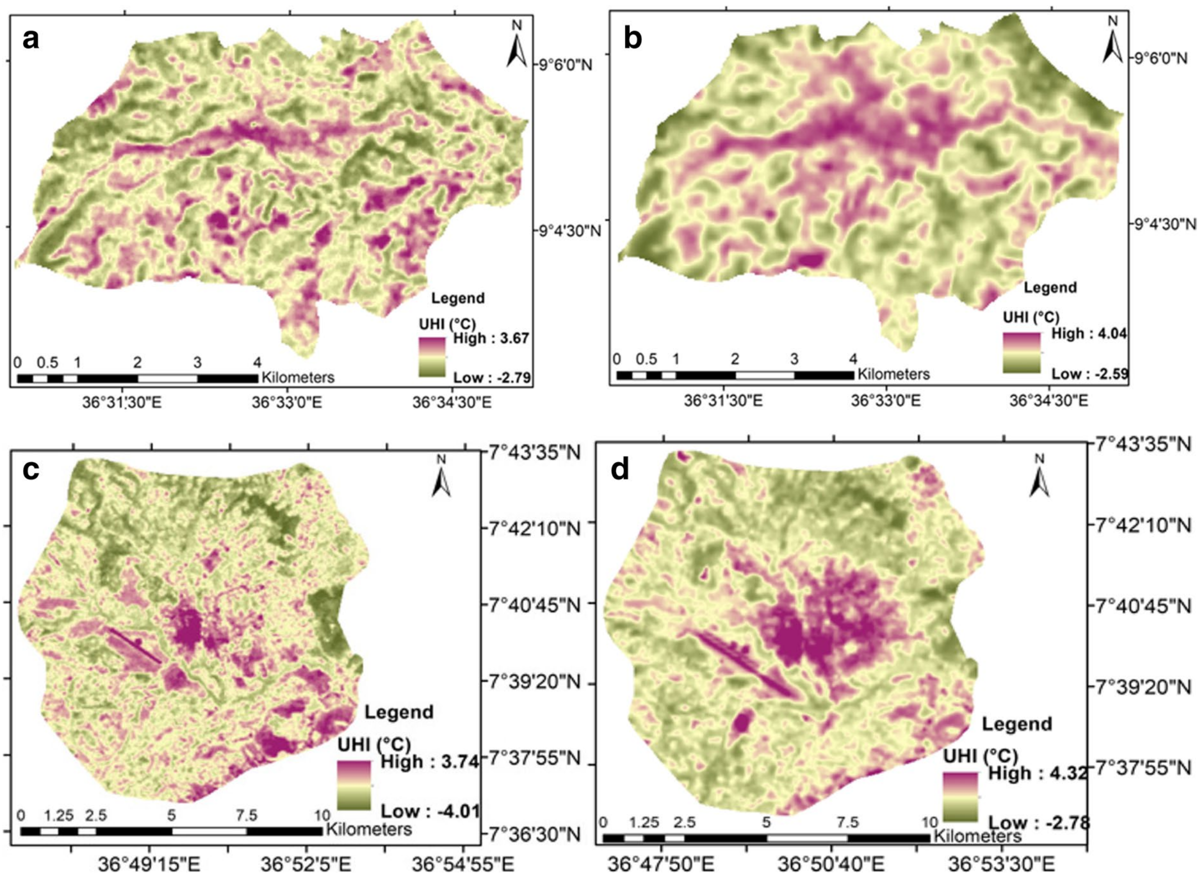


**Fig. 7** Spatial distribution of UHI for Nekemte City in 2001 (**a**) and 2021 (**b**) and Jimma City in 2001 (**a**) and 2021 (**b**)

The NDBI result reveals that LST is directly related to the NDBI. This indicates that areas with higher NDBI are associated with higher LST values. Mainly, areas with lower vegetation cover and a high concentration of built up reflected higher NDBI values in both cities. In general, NDBI and NDVI are inversely related, and NDBI have a positive relationship with LST. The spatial distribution of the NDBI for Nekemte and Jimma City is presented in Fig. 6.

### Spatial distribution of UHI

The trend and distribution of UHI are directly related to LST. Like LST, UHI is in an inverse relationship with NDVI. Areas with higher LST values have experienced higher UHI, and vice versa. Areas with good vegetation cover are associated with lower LST and UHI in both cities. The result is an indication for the fact that the increase in vegetation and green areas is significant in improving the thermal characteristics of urban areas.

The UHI values have increased from 3.67 to 4.04 and from 3.74 to 4.32 in Nekemte and Jimma City, respectively, for the study period from 2001 to 2021. The spatial distribution of the UHI presented in Fig. 7 indicates that the main variations in UHI are associated with the condition of vegetation cover and built-up concentrations.

Urbanization-induced LULC change does not only cause changes in the hydrological process but also changes the thermal variations and urban heat stress of the urban centers. Moreover, the impacts of the increase in urban LST and UHI are not only limited to the decline of ecosystem service and environmental problems but also have a profound effect on human beings. Ayanlade and Howard (2019) reported that increased heat fluxes are associated with increased mortality, especially for the elderly. Therefore, the result of this study is important for future urban development planning and management for Nekemte and Jimma City. Especially, the result shows the importance of vegetation covers in controlling the urban heat stress.

## Conclusion

This study aimed to evaluate the urban-induced LULC changes in two cities in western Ethiopia using Landsat images with the help of ERDAS Imagine, GIS, and remote sensing techniques. The LULC change analysis showed a substantial change in LULC in both cities between 2001 and 2021. The built-up and bare land areas have expanded, while open spaces, vegetation, and agricultural lands have declined. The increase in built-up areas has come at the expense of the grassland and wetlands decline, which is consistent with trends observed in most developing countries. In developing countries like Ethiopia, sociocultural and economic opportunities in urban areas attract people to migrate and settle there. The highest gain by built-up was associated with the highest loss of agricultural lands and open space areas. Being a developing country, observed data of meteorological stations are not well established in Nekemte and Jimma; consequently, the use of remote sensing data provides an opportunity to evaluate the spatio-temporal distribution of surface temperature and urban heat fluxes.

The study found a warming tendency in temperature owing to increasing urbanization-induced LULC changes in both cities. The maximum and minimum temperatures have increased by 1.9 °C (3.4 °C) and 1.4 °C (1.9 °C) from 2001 to 2021 in Nekemte and Jimma cities, respectively. The spatial distribution of LULC changes and the spatial patterns of LST are closely connected. Higher LST is reported in central areas compared to the outskirts as a result of higher built-up areas at the center in both cities. Low vegetation cover regions experience higher LST and UHI, while high vegetation cover regions experience lower LST and UHI. This suggests that the removal of vegetative areas in favor of artificially constructed surfaces causes the cities to warm up gradually as a result of the absorption of solar energy.

As urban populations continue to increase, there should be an established link between LULC and the population for sustainable development of urban areas. Moreover, evaluating urban-induced LULC changes and the associated LST is very important for planning interventions for urban heat mitigation efforts in urban areas. The LULC types are directly related to the LST, as LST is to UHI. Therefore, plans to reduce urban heat should encompass interventions that introduce green areas. In order to control the urban heat islands in urban areas, a sustainable and ambitious vision of enhanced socio-ecological resilience in the target areas with natural landscape through increasing vegetative areas and urban greenery is very important.

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**Author contribution** All the survey data, Landsat processing, image classification and analysis, and manuscript write up was done by Wakjira Takala Dibaba.

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**Data availability** The land use/land cover data sets generated during this study are available on the reasonable request from the author.

## Declarations

**Ethics approval** The author has read, understood, and have compiled as applicable with the statement on "Ethical responsibilities of authors" as found in the instructions for authors.

**Competing interests** The author declares no competing interests.

## References

Abebe, M. S., Derebew, K. T., & Gemeda, D. O. (2019). Exploiting temporal-spatial patterns of informal settlements using GIS and remote sensing technique: A case study of Jimma city, Southwestern Ethiopia. *Environmental Systems Research*, *8*(1). https://doi.org/10.1186/s40068-019-0133-5

Arsiso, B. K., Tsidu, G. M., Stoffberg, G. H., & Tadesse, T. (2017). Climate change and population growth impacts on surface water supply and demand of Addis Ababa, Ethiopia. *Climate Risk Management, 18*, 21–33. https://doi.org/10.1016/j.crm.2017.08.004

Arsiso, B. K., Tsidu, G. M., Stoffberg, G. H., & Tadesse, T. (2018). Influence of urbanization-driven land use/cover change on climate: The case of Addis Ababa, Ethiopia. *Physics and Chemistry of the Earth, 105*, 212–223. https://doi.org/10.1016/j.pce.2018.02.009

Assen, M. (2011). Land use/ cover dynamics and its implications in the dried Lake Alemaya Watershed, Eastern Ethiopia. *Journal of Sustainable Development in Africa, 13*(4), 267–284.

Ayanlade, A., & Howard, M. T. (2019). Land surface temperature and heat fluxes over three cities in Niger Delta. *Journal of African Earth Sciences, 151*, 54–66. https://doi.org/10.1016/j.jafrearsci.2018.11.027

Baram, H. O., Mohammed, O. A., Hamaamin, H. K., Hamid, A. A., & Mustafa, R. L. (2021). Urbanization and its effect on land surface temperatures in Halabja City. *Technium, 3*(7), 87–98.

Barbieri, T., Despini, F., & Teggi, S. (2018). A multi-temporal analyses of land surface temperature using Landsat-8 data and open source software: The case study of Modena, Italy. *Sustainability, 10*(5), 1–23. https://doi.org/10.3390/su10051678

Betru, T., Tolera, M., Sahle, K., & Kassa, H. (2019). Trends and drivers of land use / land cover change in Western Ethiopia. *Applied Geography*, *104*(August 2018), 83–93. https://doi.org/10.1016/j.apgeog.2019.02.007

CSA. (2007). *Summary and statistical report of the 2007 population and housing census*. Central Statistical Agency, Addis Ababa, Ethiopia.

CSA. (2013). *Central Statistical Agency: Population projection of Ethiopia for all regions at Wereda level from 2014–2017*. Central Statistical Agency, Addis Ababa, Ethiopia.

Das, N., Mondal, P., Sutradhar, S., & Ghosh, R. (2020). Assessment of variation of land use/land cover and its impact on land surface temperature of Asansol subdivision. *The Egyptian Journal of Remote Sensing and Space Sciences, 24*(1), 131–149. https://doi.org/10.1016/j.ejrs.2020.05.001

Debie, E., Anteneh, M., & Asmare, T. (2022). Land use/cover changes and surface temperature dynamics over Abaminus Watershed, Northwest Ethiopia. *Air, Soil and Water Research, 15*, 1–16. https://doi.org/10.1177/11786221221097917

Degefu, M. A., Argaw, M., Feyisa, G. L., & Degefa, S. (2021a). Dynamics of urban landscape nexus spatial dependence of ecosystem services in rapid agglomerate cities of Ethiopia. *Science of the Total Environment, 798*, 1–22. https://doi.org/10.1016/j.scitotenv.2021.149192

Degefu, M. A., Argaw, M., Feyisa, G. L., & Degefa, S. (2021b). Effects of urbanization on the relationship between greenspace patterns and evolution of regional heat island in cities of Ethiopia. *Chinese Journal of Population, Resources and Environment, 19*, 330–343. https://doi.org/10.1016/j.cjpre.2022.01.006

Degefu, M. A., Argaw, M., Feyisa, G. L., & Degefa, S. (2023). Dynamics of green spaces- Land surface temperature intensity nexus in cities of Ethiopia. *Heliyon*. https://doi.org/10.1016/j.heliyon.2023.e13274

Degife, A., Worku, H., Gizaw, S., & Legesse, A. (2019). *Land use land cover dynamics, its drivers and environmental implications in Lake Hawassa Watershed of Ethiopia*. Society and Environment. https://doi.org/10.1016/j.rsase.2019.03.005

Dessu, T., Korecha, D., Hunde, D., & Worku, A. (2020). Long-term land use land cover change in urban centers of Southwest Ethiopia from a climate change perspective. *Frontiers in Climate, 2*, 1–23. https://doi.org/10.3389/fclim.2020.577169

Dibaba, W. T. (2018). A review of sustainability of urban drainage system: Traits and consequences. *Journal of Sedimentary Environments*, *3*(3), 131–137. https://doi.org/10.12957/jse.2018.37825

Dibaba, W. T., Demissie, T. A., & Miegel, K. (2020a). Drivers and implications of land use/land cover dynamics in Finchaa catchment, Northwestern Ethiopia. *Land*, 9(4). https://doi.org/10.3390/land9040113

Dibaba, W. T., Demissie, T. A., & Miegel, K. (2020b). Watershed hydrological response to combined Land use/land cover and climate change in highland Ethiopia: Finchaa catchment. *Water, 12*(6), 1801. https://doi.org/10.3390/w12061801

Dibaba, W. T., & Ebsa, D. G. (2022). Identifying erosion hot spot areas and evaluation of best management practices in the Toba Watershed, Ethiopia. *Water Conservation and Management*, *6*(1), 30–38. https://doi.org/10.26480/wcm.01.2022.30.38

Dibaba, W. T., & Leta, M. K. (2019). Assessment the potential impacts of urbanization: Case of Jimma City. *Iranian (Iranica) Journal of Energy & Environment Journal*, *10*(3), 200–203. https://doi.org/10.5829/ijee.2019.10.03.06

Gemeda, D. O., Feyssa, D. H., & Garedew, W. (2021). Meteorological data trend analysis and local community perception towards climate change: A case study of Jimma City, Southwestern Ethiopia. *Environment, Development and Sustainability, 23*(4), 5885–5903. https://doi.org/10.1007/s10668-020-00851-6

Gobena, N. F. (2020). Nature-based drainage solution for minimizing the risk of flooding in Nekemte city [MSc Thesis, Addis Ababa University, Ethiopia].

Guechi, I., Gherraz, H., & Alkama, D. (2021). Relationship between LULC characteristic and LST using remote sensing and GIS, case study Guelma (Algeria). *Romanian Journal of Geography, 65*(2), 203–222.

Halder, B., Haghbin, M., & Farooque, A. A. (2021). An assessment of urban expansion impacts on land transformation of Rajpur-Sonarpur municipality. *KBES*, *2*(3), 34–53. https://doi.org/10.51526/kbes.2021.2.3.34-53

Halder, B., Karimi, A., Mohammad, P., Bandyopadhyay, J., Brown, R. D., & Yaseen, Z. M. (2022). Investigating the relationship between land alteration and the urban heat island of Seville city using multi-temporal Landsat data. *Theoretical and Applied Climatology, 150*, 613–635. https://doi.org/10.1007/s00704-022-04180-8

Haylemariyam, M. B. (2018). Detection of land surface temperature in relation to land use land cover change: Dire Dawa City, Ethiopia. *Journal of Remote Sensing & GIS, 7*(3), 1–9. https://doi.org/10.4172/2469-4134.1000245

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. In Core Writing Team, R. K. Pachauri, & L. A. Meyer (Eds.). IPCC, Geneva, Switzerland.

IPCC. (2019). Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

Khan, R., Li, H., Basir, M., Chen, Y. L., Sajjad, M. M., Haq, I. U., Ullah, B., Arif, M., & Hassan, W. (2022). Monitoring land use land cover changes and its impacts on land surface temperature over Mardan and Charsadda Districts, Khyber Pakhtunkhwa (KP), Pakistan. *Environmental Monitoring and Assessment*, *194*(6). https://doi.org/10.1007/s10661-022-10072-1

Kuddus, A., Tynan, E., & Mcbryde, E. (2020). Urbanization: A problem for the rich and the poor? *Public Health Reviews*, *41*(1), 1–4. https://doi.org/10.1186/s40985-019-0116-0

Mezgebo, T. G. (2021). Urbanization and development in Ethiopia: Policy issues, trends and prospects. In Mengistu K. & Getachew D. (Ed.), *State of the Ethiopian Economy 2020/2021: Economic Development, Population Dynamics and Welfare:Addis Ababa: Ethiopian Economic Association*.

Miheretu, B. A., & Yimer, A. A. (2017). Land use / land cover changes and their environmental implications in the Gelana sub _ watershed of Northern highlands of Ethiopia. *Environmental Systems Research*, *6*(7). https://doi.org/10.1186/s40068-017-0084-7

O'Driscoll, M., Clinton, S., Jefferson, A., Manda, A., & Mcmillan, S. (2010). Urbanization effects on watershed hydrology and in-stream processes in the Southern United States. *Water, 2*, 605–648. https://doi.org/10.3390/w2030605

Oloke, O. C., Fayomi, O. S. I., Oluwatayo, A., Adagunodo, T. A., Akinwumi, I. I., & Amusan, L. (2021). The nexus of climate change, urban infrastructure and sustainable development in developing countries. *IOP Conference Series: Earth and Environmental Science*, 012051. https://doi.org/10.1088/1755-1315/665/1/012051

Pal, S., & Ziaul, S. (2017). Detection of land use and land cover change and land surface temperature in English Bazar urban centre. *Egyptian Journal of Remote Sensing and Space Science, 20*, 125–145. https://doi.org/10.1016/j.ejrs.2016.11.003

Perry, G., Gebresenbet, F., Dapra, M., Branco, P., Whibesilassie, W., Jelacic, M., & Eyob, A. E. (2022). Why urban ecology matters in Ethiopia. *Frontiers in Ecology and Evolution, 10*, 1–10. https://doi.org/10.3389/fevo.2022.843698

Pulighe, G., Baiocchi, V., & Lupia, F. (2015). Horizontal accuracy assessment of very high-resolution Google Earth images in the city of Rome, Italy. *International Journal of Digital Earth, 9*, 342–362. https://doi.org/10.1080/17538947.2015.1031716

Stemn, E., & Kumi-Boateng, B. (2020). Modelling of land surface temperature changes as determinant of urban heat island and risk of heat-related conditions in the Wassa West Mining Area of Ghana. *Modeling Earth Systems and Environment, 6*, 1727–1740. https://doi.org/10.1007/s40808-020-00786-x

Tadele, H., Mekuriaw, A., Selassie, Y. G., & Tsegaye, L. (2017). Land use / land cover factor values and accuracy assessment using a GIS and remote sensing in the case of the Quashay watershed in northwestern. *Journal of Natural Resources and Development, 07*, 38–44. https://doi.org/10.5027/jnrd.v7i0.05

Temesgen, H., Wu, W., Legesse, A., Yirsaw, E., & Bekele, B. (2018). Landscape-based upstream-downstream prevalence of land-use/cover change drivers in southeastern rift escarpment of Ethiopia. *Environmental Monitoring and Assessment*, *190*(3). https://doi.org/10.1007/s10661-018-6479-8

Viera, A. J., & Garrett, J. M. (2005). Anthony J. Viera, MD; Joanne M. Garrett, PhD (2005). Understanding interobserver agreement: The kappa statistic. *Family Medicine*, *37*(5), 360–363.

Wang, Y., Yi, G., Zhou, X., Zhang, T., Bie, X., Li, J., & Ji, B. (2021). Spatial distribution and influencing factors on urban land surface temperature of twelve megacities in China from 2000 to 2017. *Ecological Indicators, 125*, 1–16.

World Bank Group. (2015). *Ethiopia Urbanization Review: Urban Institutions for a Middle-Income Ethiopia.* https://openknowledge.worldbank.org/handle/10986/22979. License: CC BY 3.0 IGO.

Yesuph, A. Y., & Dagnew, A. B. (2019). Land use/cover spatiotemporal dynamics, driving forces and implications at the Beshillo catchment of the Blue Nile Basin, North Eastern Highlands of Ethiopia. *Environmental Systems Research*, *8*(21). https://doi.org/10.1186/s40068-019-0148-y

Zhao, A. Z., He, B., Li, L., Wang, H.-B., & Darko, A. (2017). Profile and concentric zonal analysis of relationships between land use/land cover and land surface temperature: Case study of Shenyang, China. *Energy & Buildings*. https://doi.org/10.1016/j.enbuild.2017.09.046

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