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Urbanization and urban land use efficiency: Evidence from regional and Addis Ababa satellite cities, Ethiopia

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ABSTRACT

Ethiopia has experienced rapid urbanization over the past three decades. Several cities expanded rapidly and many satellite towns sprung up around the major cities. The high rate of urbanization and urban growth resulted in high demand for urban land, mainly for industrial, commercial, and residential purposes. In order to meet the demand, an enormous amount of land has been made available for urban use, mainly through land conversion. However, we know very little about how efficiently cities use urban land. This paper investigated the urban land use efficiency (ULUE) of sixteen cities in Ethiopia. Remote sensing data (Landsat 7/8) was analysed with ArcGIS to assess spatiotemporal land use changes between 2007 and 2019. Built-up environment footprints were computed from Google Earth imagery. The ratio of land consumption to population growth rate, and the rate of urban infill were assessed. The findings revealed a prevalence of urban land use inefficiencies in all cities. In most cities, the rate of land consumption far exceeds the population growth rate. Densification (urban infill) is low and slow. A considerable part of the converted agricultural land sits idle within the built-up area for many years. Low ULUE is what fuels urban sprawl, fragmentation and informal settlements. This study emphasised the need to implement urban policies and practices aimed at improving ULUE. Improving ULUE is imperative to achieve the Sustainable Development Goals; ensuring sustainable urban land use; addressing land prices and housing shortages; protecting farmland and ecosystems; tackling land hoarding, urban sprawl and informal settlements.

1. Introduction

Urbanization is one of the demographic mega-trends that has played a significant role in terms of shaping the built environment (UN DESA, 2019; UN-Habitat, 2020a). In 2018, 55.2% of the global population lives in urban areas. By 2050, the number of people who live in urban areas is projected to reach 68% (UN DESA, 2019). About 90% of the increase, according to UN (2019), will come from Asia and Africa. At the moment, urbanization in Africa is 43% (UN, 2019).

Between 2000 and 2015, according to Saghir and Santoro (2018), Sub-Saharan Africa (SSA) has experienced an annual urban population growth rate of 4.1%. With 6.5%, the annual population growth rate is even higher in East Africa (OECD, 2020b). This is very high compared with a global rate of 2.0%. About 40% of Africa's urban population growth is a result of rural-to-urban migration (World Bank Group, 2021). As the continent tries to catch up with the rest of the world, the rate of urbanization is expected to be much faster in Africa between now and 2050 (OECD, 2020b).

Urbanization[1] refers not only to the percentage change in population dwelling in urban centres but also to the size of the area occupied by urban settlements (UN, 2019). Globally, the rate of urban areas expansion outpaces the population growth rate. Between 2000 and 2014, the average rate of urban boundaries expansion was 1.3 times faster than their population (UN ECOSOC, 2019; United Nation-HLPF & UN, 2018). Urban expansion is much faster in developing countries. For instance, in SSA built-up area expanded by an average of 4.8% between 2000 and

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[1] 'Urbanization refers to change from rural to urban ways of living characterized by a predominance of economic activities other than agriculture. Urban growth refers to an increase in the absolute number of people living in urban areas. Urban expansion concerns the physical enlargement of built-up urban areas (World Bank Group, 2017: p 1)'.

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2015. During this period, smaller cities expanded by an average of 5.4% annually in the region (Forget, Shimoni, Gilbert, & Linard, 2021). Since 1990, an area equivalent to the UK has been taken up by built-up areas globally (Haščič & Mackie, 2018).

Urbanization in Ethiopia is 21.2% in 2019 (UN DESA, 2019). This is very low even compared with SSA countries (Schmidt, Dorosh, Jemal, & Smart, 2018). However, Ethiopia is a country experiencing fast urbanization. The urban population increased by 4.2% per year between 1994 and 2015 (Schmidt et al., 2018). Since 2011, the annual growth rate has reached 6.2% (World Bank, 2020a). In 2050, the country's proportion of the urban population is projected to reach 39% (UN DESA, 2019).[2] For instance, Addis Ababa's (Ethiopia's capital) population has doubled since 2000. It is expected to almost double again by 2035 reaching 7.17 million (Lustgarten, 2020). According to the World Bank (2021), migration will be the major factor behind Addis Ababa's population change. Nonetheless, the largest portion of Ethiopia's urbanization is taking place in intermediary cities and small towns (OECD/PSI, 2020; World Bank, 2017). This trend, according to Schmidt et al. (2018), will continue for the coming two decades.

In the country, over the past two decades, urbanization and economic development have led to the unprecedented expansion of urban boundaries, both in major and smaller cities. For instance, from 2007 to 2014, Addis Ababa's total area increased by 51% (Ozlu et al., 2015). During this period, the city's rate of urban expansion outpaced its population growth rate (Koroso, Zevenbergen, & Lengoiboni, 2020). Between 2000 and 2015, the built-up area of the cities of Hawassa and Bahir Dar increased by 284% and 148% respectively (UN-Habitat, 2020b). In Bahir Dar, Admasu et al. (2019) wrote, boundary expansion was made possible through farmland conversion. A significant portion of rural land, especially in peri-urban areas, has been made available for urban land use. As a result, rural land conversion and farmland loss have been the defining feature of urbanization in the country.

Urbanization has largely contributed to economic growth, poverty reduction, and human development (UN, 2019). Nevertheless, rapid urbanization in the form of urban expansion, specifically when unplanned, leads to undesirable consequences (World Bank, 2017). Balancing fast urban population growth and efficient resource use has become a challenge, particularly in developing countries (OECD, 2020b). Disproportionate urban expansion poses social, economic and environmental challenges (Shao et al., 2020). Globally, there is a trend of declining urban densities (UN ECOSOC, 2019). The fast rate of urban expansion, mainly in the form of urban sprawl, has consequences on urban density, urban morphology, land use efficiency, infrastructure and service provision, farmland and ecosystem protection, etc (Dadi et al., 2016; Guida-Johnson, Faggi, & Zuleta, 2017; Terfa, Chen, Zhang, & Niyogi, 2020; UN-Habitat, 2020a; World Bank, 2020b). According to the UN ECOSOC, this has a repercussion on environmental sustainability and food security at a regional and global level. For example, because of the high rate of urban growth worldwide, 1.8–2.4% of cropland will be lost due to urban expansion by 2030 (D'Amour et al., 2017). Countries in Africa and Asia will be the most affected, according to D'Amour.

According to UN-Habitat (2018a), in many countries, population growth, increasing per capita incomes, and the proliferation of informal settlements are the major driving forces behind the phenomenon of fast urban expansion. Inefficient urban land use, including land fencing and land oversupply, might have also played a role in aggravating the situation (Koroso, Zevenbergen, & Lengoiboni, 2019). To tackle the challenges urbanization and urban growth pose, it is imperative to have an effective system of urban planning and governance, particularly in low and middle-income countries (OECD, 2020a; UN DESA, 2019).

Urban land is becoming a scarce resource in many countries (Lambin & Meyfroidt, 2011). Yet in many parts of the world, a significant part of urban land has not been used efficiently. In some countries, because of fencing and land hoarding, large tracts of urban land remained unproductive (Dadi et al., 2016; Du & Peiser, 2014; Gemeda, Abebe, Paczoski, Xie, & Cirella, 2019; Koroso et al., 2020; Steel, Abukashawa, & Hussein, 2020; Zhang et al., 2015). Therefore, efficient use of urban land is required to address issues related to fast urbanization, industrialization, speculation, farmland protection, etc.

To ensure sustainable urbanization, the management of urban growth plays a pivotal role. To realize this, the UN, under its Sustainable Development Goals (SDG), has set a target (SDG 11.3) to achieve sustainable urban growth by 2030 (United Nations, 2015). Similarly, the New Urban Agenda also underscores the need for well-managed urbanization for a shared and sustainable development (United Nations, 2017). Ensuring efficient and sustainable urban land use is one of the goals outlined under SDG 11. One way of realizing this is by limiting urban sprawl and avoiding unjustifiable land use changes (United Nations, 2017). SDG 11.3 promotes a move towards achieving realistic urban density and compactness than embarking on unsustainable urban expansion. Compact cities use land more efficiently and are also suitable to provide better public goods and services (Duque, Lozano-Gracia, Patino, & Restrepo, 2019; Global Platform for Sustainable Cities, 2018; Lall, Henderson, & Venables, 2017; UN-Habitat, 2018).

Sustainable urbanization cannot be realized without finding the right balance between urban growth and urban expansion. Understanding how fast urban areas expand and urban population change is crucial to grasp the evolution of urban settlements. This, for instance, helps us recognize how fast peri-urban areas (farmland, forest and protected areas) are being consumed by expanding cities (UN-Habitat, 2018). It might also give us a clue about the cities' land use efficiency. Efficient urban land use is essential to attain 'sustainable urban growth and coordinate economic development and environmental protection' (Han, Zhang, & Cai, 2020). The degree of ULUE, furthermore, affects housing prices and the cost of service provision (Wang, Cebula, Liu, & Foley, 2020). In addition, the efficiency of urban land use has implications for economic productivity and energy consumption (Global Platform for Sustainable Cities, 2018; Lall et al., 2017). Therefore, a good understanding of ULUE is imperative for evidence-based urban planning and management, land conversion and environmental protection. An assessment of ULUE helps policymakers not only to know how efficiently urban land has been used but also to "formulate policies that encourage optimal use of urban land, effectively protecting other land uses (natural environments, farmlands, etc)" (UN-Habitat, 2018).

This research focuses on exploring the effects rapid urban expansion has on ULUE. Emphasis is on the assessment of how efficiently and productively urban lands (converted for residential, industrial and commercial purposes) have been used in Ethiopia. The status of urban land use efficiency in the country has not been properly studied. In this study, we investigate the rate of urban expansion, land consumption[3] and densification[4] to analyse ULUE in major cities in the country. Studying ULUE in Ethiopia is interesting because of the following factors: rapid urbanization and urban expansion; rampant urban sprawl and informal settlements; state ownership of urban and rural land; and the use of land conversion as a policy tool to generate revenue to finance municipal infrastructure. Ethiopia, like China and Vietnam, is one of the few countries in the world with a policy of state land ownership and land-based financing.

[2] Ethiopia's total population are projected to reach 191 million in 2050.

[3] According to the UNSD (2021), the land consumption rate is the rate at which urbanized land or land occupied by a city/urban area changes during a period, expressed as a percentage of the land occupied by the city/urban area at the start of that time.

[4] Densification describes the increasing density of people living in urban areas. It can be measured, among other things, by a residential density (UN-Habitat, 2020a). In this paper, densification refers to urban infill, which is a development of unbuilt parcels within an existing built-up environment (S. V. Lall et al., 2017; Pelczynski & Tomkowicz, 2019).

The second section of this paper focuses on a literature review. In the third section, methods will be addressed. Results and discussion will be addressed under sections four and five, respectively. Finally, the conclusion summarizes the findings and highlights policy implications.

2. Literature review

Land Use Efficiency is defined in different ways from different perspectives. According to Liu, Ye, and Li (2019), it is a degree of interaction between human economic activities and natural subsystems. Other scholars defined it as a measure of an input-output ratio measured in terms of factors such as land, capital, and labour (Chen, Chen, Xu, & Tian, 2016). According to this definition, it is about how much economic gain has been made as a result of using the land. Land use efficiency, in another way, is an indicator of how productively and sustainably land, as a resource, is being used. Land use efficiency can also be defined as the ratio between urban area expansion (land consumption) and population growth rate[5] (Corbane, Politis, Siragusa, Kemper, & Pesaresi, 2017; Zhang, Zhang, Xu, Zhou, & Yeh, 2020; Zitti et al., 2015). This means it is a measure of built-up area density.[6] Better density improves agglomeration of economies (Lall et al., 2017). This study, nevertheless, focuses on investigating whether urban land is being utilized effectively rather than measuring economic output as a result of using the land.

Urbanization is increasingly pushing urban boundaries. It is posing serious challenges to farmlands, forests, protected areas, etc. This is leading to eviction and loss of livelihood; especially in peri-urban areas. Excessive built-up area expansion and inefficient urban land use, for example, have led to a shortage of land resources in China (Chen et al., 2016). In the country, the rate of construction land expansion outpaced the urban population growth rate. Land consumption to population growth ratio, which is 1.96 not only high but also nearly double what is suggested by the China Urban Planning and Design Institute (Zhang et al., 2020). In Great Britain, between 2013 and 2016, land consumption and the population grew by 4.3% and 1.5% respectively (UK Office for National Statistics, 2018). The significant gap exhibited between land consumption and population growth rate has an adverse effect on ULUE. The degree of urban land use efficiency, in general, affects traffic, energy use, urban infrastructure, etc. in different ways (Claassens & Koomen, 2018).

The degree of ULUE exhibited within a country differs. Studies revealed ULUE varies across regions and cities (Jiao et al., 2020; Wang, Li, & Shi, 2015). Land use efficiency of urban expansion area and areas at the peripheries are relatively low, wrote Huang and Xue (2019). It is associated with a different stage of economic development, according to Chen et al. (2016). Economically developed regions tend to achieve a better ULUE score. ULUE in “old urban areas and mature built-up areas” are relatively high (Huang & Xue, 2019). Furthermore, Zhao, Zhang, Huang, Zhao, and Zhang (2018) claimed, ULUE is positively associated with the agglomeration of industries, labour, capital, and technology. There are other factors defining ULUE such as population density, investment, fiscal expenditure, transportation infrastructure, land marketization, type of land, etc. (Wang et al., 2015). Additionally, land policy effectiveness, particularly in areas of lease policy enforcement (Koroso et al., 2020), land management (Zitti et al., 2015) and zoning plan implementation are other crucial ULUE defining factors.

Furthermore, political ideology and type of land ownership have effects on land use efficiency. Chinese socialist legacy has severely compromised ULUE and failed to curtail pervasive illegal activities, Lin and Ho (2005) claimed. According to Lin and Ho, municipalities focus on revenue generation from the land sale served as an incentive for a massive peri-urban land conversion with little regard for land use efficiency and densification. Corruption and weakness in land policy enforcement have further aggravated problems related to land use efficiency (Lin & Ho, 2005).

Land hoarding, land banking and land oversupply have significant effects on ULUE. It seems that low ULUE is rampant in countries where urban land is under state ownership. Hoarding, for instance, is a serious challenge to ULUE in China (Zhang et al., 2015). Not only developers but also government officials engage in this practice (Du & Peiser, 2014). In Vietnam, likewise, the current institutional arrangement is not effective against tackling land hoarding, Ha and Nguyen (2019) argued. For instance, the law requires projects, which sit idle for over 12 months, to be revoked. However, according to Ha and Nguyen, various factors, including inspectors’ incompetence affect enforcement.

Bad practices of urban land management in Ethiopia are one of the reasons behind ULUE, explained in terms of the high land price, land hoarding, low density, informal settlement and urban sprawl (Koroso et al., 2020; Ozlu et al., 2015; Terfa et al., 2020; World Bank Group, 2019). Because of built-up areas’ encroachment into rural areas, farmland loss and urban sprawl have become a common phenomenon of urbanization in the country (Dadi et al., 2016; Terfa et al., 2020).

Countries use various policy instruments to address land use inefficacies. Industrial agglomeration (concentrating industries in a given area) (Zhao et al., 2018) and densification (urban infill) (Wang, Huang, Feng, Zhao, & Gu, 2020) can be some of the policy instruments. Farmland protection, control of land fragmentation and urban sprawl are other measures to deal with land use inefficacies. In the case of low land inefficiencies due to fencing and land oversupply, strict land policy/law enforcement might be appropriate to address gaps (Dadi et al., 2016; Koroso et al., 2020). There are indications that state land systems undermine urban land use efficiency. Based on Chinese experiences, Lin and Ho (2005) argued that a market approach to urban land transfer leads to efficient urban land use. That means market-oriented urban land supply might help alleviate challenges related to urban land use inefficiencies. This is mainly because it is less likely to fence land acquired at market value than land acquired below market value for ‘investment’ (Koroso et al., 2020; Ozlu et al., 2015). Urban growth policy should focus on improving land use efficiency through, for instance, smart growth, which discourages urban sprawl (Gabriel, Faria, & Moglen, 2006). Also, it has to encourage intensive use of land within a city boundary rather than following a path of unstainable expansion (Hepinstall-Cymerman, Coe, & Hutyra, 2013) and encroachment into farmlands.

In recent years, ULUE has attracted the attention of researchers. The studies, nonetheless, largely focused on China (Gao, Zhang, & Sun, 2020; Jiao et al., 2020; Liu et al., 2019; Lu, Chen, Kuang, Zhang, & Cheng, 2020; Wang et al., 2015; Zhao et al., 2018). While most of the African cities are expanding rapidly and in a fragmented manner, resulting in urban sprawl, urban land use efficiency assessment has not received enough attention. Few scholars, nevertheless, attempted to investigate ULUE in African cities (Bakker, Verburg, & van Vliet, 2021; Estoque, Ooba, Togawa, Hijioka, & Murayama, 2021; Hu, Wang, Taubenböck, & Zhu, 2021). Most of the studies are still at the regional level. There are, however, few country and city-level studies (Fenta et al., 2017; Koroso et al., 2020; Mudau et al., 2020). Improving urban land use efficiency is one of the SDG goals. In addition, urban land use efficiency is essential for sustainable economic growth and environmental protection. Therefore, it is imperative to pay due attention to understanding ULUE in African cities.

The focus of ULUE studies in China has largely been on analysing how much urban land has contributed economically, measured in terms of, for example, GDP contribution and labour output (Chen et al., 2016; Danni, 2019; Gao et al., 2020; Lu et al., 2020). Chen et al. (2016) investigated ULUE of 336 Chinese cities from 2005 to 2010. Their study revealed that more than half of the cities studied do not use land efficiently. ULUE, they claimed, is low even in the most developed parts of the country. Huang and Xue (2019) investigated ULUE of Chinese cities

[5] This is the definition we carry forward.

[6] In this paper built-up area density refers to the built-up areas footprints as opposed to the height of buildings (number of floors).

at the districts and counties level. Their finding showed that ULUE improvement is needed. Research by Wang, Huang, Feng, Zhao, and Gu (2020) revealed a large scale efficiency loss in three major urban agglomerations of China, and the trend shows a further increase in use inefficiencies. Similarly, the overall ULUE of Vietnamese cities is low, Danni (2019) claimed.

Additionally, there are land use efficiency related studies conducted in some African cities (Kleemann et al., 2017; Koroso et al., 2020; Steel et al., 2020; van Noorloos & Kloosterboer, 2018; Xu et al., 2019). For example, the study conducted by Larsen et al. (2019) showed that the urban density of Addis Ababa has decreased. In Dukem, rapid agricultural land conversion and keeping industrial land vacant adversely affected productivity (Dadi et al., 2016). Besides, according to Mengistu and van Dijk (2018), transferring lease rights (subleasing) before developing the land is one of the reasons negatively affecting land use efficiency in Ethiopia. Because of gaps in enforcement, speculators fence plots for years (Gemeda et al., 2019; World Bank, 2012). This emanates mainly from weak follow-up and/or lack of commitment to ensure urban land user rights holders use the land for intended purposes than hoarding it.

There are various methods used to conduct ULUE analysis. Some researchers used Data Envelopment Analysis (DEA) (Danni, 2019; Huang & Xue, 2019; Xing & Sun, 2013; Zhu et al., 2019). Scale-adjusted metropolitan indicators (Jiao et al., 2020), exploratory spatial data analysis (Liu et al., 2019), stochastic frontier analysis (Wang, Huang, et al., 2020) and slacks-based measures (Lu et al., 2020) are also methods employed to study ULUE. Because of a lack of city-level panel data (Goldblatt, Deininger, & Hanson, 2018) on variables such as energy consumption, labour output, GDP contribution, industrial emission, discharge of waste, etc. the above methods are not well-fitted methods for this study.

The ratio of urban expansion to population growth within a specified time is another method used to measure ULUE (Koroso et al., 2020; Mudau et al., 2020; Nicolau, David, Caetano, & Pereira, 2019; Wang, Huang, et al., 2020). This technique measures, according to UN-Habitat (2018b), how much land cities consume in relation to their population growth. For its suitability and data availability, this research employs this method to assess ULUE. We used the following formula.

3. Methods and materials

3.1. Study area and context

The study of ULUE in Ethiopia is interesting primarily due to two factors. First, urban land is under state ownership. Second, over the past two decades, the government transferred thousands of hectares to individuals, companies and public institutions for urban use largely through administrative allocation, allotment and auction. As a result, urban boundaries expanded enormously and farmers lost their land and livelihoods because of expropriation (Ambaye, 2015). The next section will show how we studied ULUE in Ethiopian cities.

In this study, we assessed ULUE in sixteen Ethiopian cities: ten regional cities and six Addis Ababa satellite cities. Adama, Bishoftu, Shashemenne and Jimma are from Oromia Region. From Amhara region, Bahir Dar and Gonder were selected. Mekele, Hawassa and Jijiga were chosen from Tigray, Southern and Somalia region, respectively. Among Addis Ababa's satellite cities, Legetafo, Sululta, Burayu, Sebeta, Gelan and Dukem were included in this study.[7]

These cities have been purposively selected for several reasons. First, to reflect regional diversity, both geographical and administrative, within the country. This is useful to study the status of ULUE in Ethiopia. Also, to compare similarities and differences among cities. Second, these cities have witnessed unprecedented urban expansion over the past 20 years (Terfa et al., 2019). Third, as a result of boundary expansion, a massive farmland conversion happened in the peri-urban areas of these cities. In most cases, this led to urban sprawl and land use fragmentation (Adam, 2014). There are also cases of immense informal settlement expansion. Fourth, municipalities have been using land sale as a policy tool to finance urban infrastructure. Studies showed that reliance on land as a source of municipal revenue incentivises excessive peri-urban land conversion (Ozlu et al., 2015; UN-Habitat, 2020a; Wang, Huang, et al., 2020; World Bank, 2020b). This apparently undermines a quest for efficient and sustainable urban land use. Furthermore, availability of data and population size has also been taken into account when selecting the study areas. A combination of these factors makes the study of ULUE in these cities and in Ethiopia a logical choice.

3.2. Data sources

The investigation of ULUE in the study area is mainly based on remote sensing and secondary data. A combination of spatial (remote sensing) and statistical data was used for our analysis. This approach can be useful to conduct a quantitative land use efficiency analysis (Cai, Zhang, Du, Li, & Peng, 2020). Landsat imageries are suitable for urban expansion analysis (Bagan & Yamagata, 2012). Therefore, to assess land cover and land use change, densification, degree of urban sprawl and land fencing (hoarding), a time series of Landsat 7 and 8 (30m * 30m resolution) satellite imagery was analysed. The imageries were downloaded from USGS Earth Explorer.[8] The imageries we used for the study were acquired in 2007, 2014 and 2019. Landsat 7 scan line error was corrected using Landsat Toolbox. To calculate the change in built-up area Landsat composite images were created and supervised classification was conducted using ArcGIS (Li, Zhou, & Ouyang, 2013; Tian, Ge, & Li, 2017). Land cover was classified into built-up, open spaces (mostly barren land), vegetation cover (farmlands, trees and forest) and water mainly for the sake of simplicity (Gong, Hu, Chen, Liu, & Wang, 2018). The focus is on understanding the proportion of the built-up areas compared to open spaces (including bare land) and vegetation cover (including farmlands).

Furthermore, high-resolution Google Earth imagery history has been used for built-up area computation. Besides, visual analysis was conducted to validate the built-up area footprints. Google Earth imagery, with 1m $\times$ 1m resolution, is ideal for spatiotemporal change analysis (Gong et al., 2018; Malarvizhi, Kumar, & Porchelvan, 2016; UN-Habitat, 2018; Wang et al., 2012; Wibowo, Salleh, Frans, & Semedi, 2016). According to Hu et al. (2013), with a classification accuracy of 78.07%, Google Earth imagery is suitable for mapping land use/cover change.

This study focused on investigating urban land use efficiency from 2007 to 2019. We use a time interval of $\pm$ 5 years for our analysis (UN-Habitat, 2018). To limit the effects that seasonal changes might have on classification accuracy, satellite imagery taken between June and October were given priority as it enables easy differentiation among open spaces and built-up areas.[9] Efforts were made to get cloud-free imageries. Although the level of accuracy varies between the study areas and the years involved, this study achieved an average overall image accuracy assessment of 87% for the study areas. Population data for this study was obtained from the Central Statistical Agency (CSA) of Ethiopia (census and projected data). Population data for the year 2019 was projected based on previous years.

[7] All the satellite cities are in Oromia Region administratively.

[8] Downloaded from USGS Earth Explorer (https://earthexplorer.usgs.gov/).

[9] In most of the study areas, June to September is a rainy season.

3.3. ULUE: Criteria for analysis

This study focuses on investigating ULUE in urban areas. Urban boundaries' extent, mainly built-up area footprint[10], are not limited to administrative boundaries (UN-Habitat, 2018). In this study, it refers to urban areas where urban land uses (urban settlement, infrastructure, etc.) are exhibited. This could be within or outside the administrative boundaries.

To assess how efficiently urban land has been used, we will assess the pattern of urban expansion and densification (urban infill) using spatiotemporal land use and land cover changes (Hepinstall-Cymerman et al., 2013). Here, it is worth noting that most Ethiopian cities do not have enough dedicated public spaces. Furthermore, open spaces in many cities are shrinking because of pressure from developers (Abebe & Megento, 2016; Azagew & Worku, 2020; Girma, Terefe, & Pauleit, 2019). Therefore, most of the open plots within the built-up area, fenced or cultivated, are mostly meant (allocated) for residential, industrial and commercial land uses. Vacant spaces, in this context, are land initially allocated for industrial, commercial and residential uses but remained unutilized for years because of various reasons. We also purposively selected land allocated for investment and residential uses and analysed use changes over years. This is to find out if urban land use efficiency varies across various land use types. We focused on comparing residential and industrial uses. To investigate the rate of land consumption and population growth, this paper used the following formula.

$$LCR = \frac{LN\left(\frac{Urb(t2)}{Urb(t1)}\right)}{Y} \quad (1)$$

$$PGR = \frac{LN\left(\frac{Pop(t2)}{Pop(t1)}\right)}{Y} \quad (2)$$

$$LCRPGR = \frac{LCR\ (builtup\ area\ expansion)}{PGR\ (population\ growth)} \quad (3)$$

where:

LCR is the land consumption rate.
PGR is the population growth rate.
Urb is the total urban built-up area.
Pop is the total population of the built-up area
t1 is the initial year *t2* is the final year.
Ln is the natural logarithm.
Y is the number of years between two measurement periods.

LCRPGR is the ratio of land consumption rate to the population growth rate. LCRPGR is a simple but effective way of measuring ULUE, which is an indicator of SDG 11.3 (Mudau et al., 2020).

Under normal circumstances, the land consumption rate (LCR) should go hand in hand with the population growth rate (PGR). A rate of urban expansion (land consumption), which is faster than urban population growth, means inefficient urban land use. There are three common values of LCRPGR: $0 \leq$ LCRPGR ≤ 1. Here, population growth is greater than land consumption. It reveals densification, which is an indicator of efficient land use. $1 <$ LCRPGR < 2 demonstrates LCR that is greater than PGR. This is a case of low density and confirms inefficient land use. If LCRPGR is > 2, the LCR is at least twice the PGR (Melchiorri, Pesaresi, Florczyk, Corbane, & Kemper, 2019; Wang, Huang, et al., 2020).

Moreover, we use the built-up area densification (urban infill), a development of unbuilt parcels within the existing built-up environment, to analyse ULUE. Densification measures how much vacant land (fenced plots) within existing urban boundaries have been developed.

$$Densification = \frac{built-up\ area\ t2\ -\ built-up\ area\ t1}{built-up\ area\ t1} \times 100 \quad (4)$$

where: *t1* represents the initial year *t2* represents the final year.

When measuring densification, urban boundary *t2* should be the same as urban boundary *t1*.

A couple of cities were not included in some aspects of land use efficiency analysis. For instance, two regional (Jima and Dire Dawa) and satellite (Sebeta and Burayu) cities were not included in the densification analysis. Legetafo, Gelan and Dukem, among satellite cities, were excluded from LCRPGR analysis. This is primarily due to the lack of reliable population data. Moreover, regional cities and satellite cities were separately assessed. This is mainly because of reasons such as demography and geographic proximity to the capital.

Regarding industrial vs residential land use efficiency assessment, we focused on four cities: Hawassa, Bahir Dar, Sululta and Dukem. From regional cities and Addis Ababa satellite cities, two cities were selected from each purposively. While selecting the cities, geographic diversity was considered. We believe these four cities provide a good picture of land use efficiency differences among industrial and residential land uses.

4. Results

4.1. The state of urban land use efficiency in the regional cities

4.1.1. Built-up area expansion

All the cities involved in this study experienced phenomenal population growth and built-up area expansion between 2007 and 2019 (Table 1, Figs. 2 and 3). The average built-up area expansion for the regional cities was 115%. Among the cities, Jijiga and Hawassa witnessed the fastest expansion during this period. Within twelve years, they expanded by 277% and 180%, correspondingly. Bishoftu and Mekele, with 32% and 71% respectively, were the least in terms of built-up footprint expansion (Fig. 1).

4.1.2. Urban land consumption and urban population growth

We measured the land consumption rate of the regional cities between 2007 and 2019. All the regional cities witnessed an average LCR of 6.02. The highest and the lowest LCR, during this period, was recorded in Jijiga (11.06) and Bishoftu (2.4), correspondingly. In general, with 11.6 and 8.65, Jijiga and Hawassa, respectively, were the two cities with the highest LCR index (Fig. 4).

Furthermore, comparing the time interval between 2007 - 2014 and 2014–2019, the highest land consumption, with an average of 6.23 LCR, was experienced after 2014 in most of the cities. The only exceptions were Hawassa, Jijiga, Dire Dawa and Jima. For these cities, LCR from 2007 to 2014 was higher than the LCR index from 2014 to 2019.

Between 2007 and 2019, all the regional cities had an average population growth rate of 4.63 (Fig. 5). Hawassa and Mekele, with 7.17 and 5.16 PGR score, respectively, experienced the highest PGR. With 2.42 and 3.03 PGR score, Dire Dawa and Jijiga, respectively, were the lowest in terms of PGR. Additionally, between 2007 - 2014 and 2014–2019, all the regional cities witnessed an average population growth rate of 5.08 and 4.0, respectively. The PGR was higher during the period from 2007 to 2014. Hawassa (8.38) and Dire Dawa (1.99) were the highest and the lowest, consecutively. From 2014 to 2019, Hawassa (5.49) and Bahir Dar (1.78) witnessed the highest and lowest PGR, sequentially.

4.1.3. LCRPGR index of the regional cities

From 2007 to 2019, the average LCRPGR of the regional cities was

[10] Built-up area footprint in this case is land used for houses, buildings, industrial structures, roads, carparks, etc. In this study, built-up and developed areas are interchangeably used.

Table 1
Population of the regional cities in Ethiopia.[a]

	Adama	Hawassa	Bishoftu	Bahir Dar	Mekele	Shashe menne	Jijiga	Dire Dawa	Gonder	Jima
2007	222,035	159,013	99,928	180,094	215,546	102,062	125,584	233,224	206,987	120,960
2014	308,526	285,785	147,064	297,794	307,304	140,717	154,183	268,000	306,246	169,446
2019	392,860	376,021	171,332	325,506	400,218	179,178	180,585	311,740	368,068	215,760

[a] Population data for the years 2007 and 2014 is from the CSA of Ethiopia (census & projection). We computed population data for the year 2019 using a population projection formula (Nt = Per*t) based on population growth rate from 2014 to 2017.

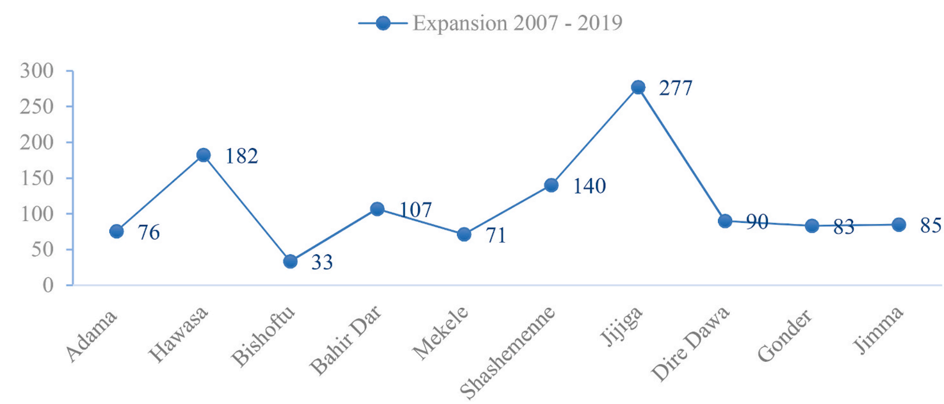

Fig. 1. Built-up area footprint expansion of the regional cities 2007–2019 in percentage.

1.44, which shows low land use efficiency. During this period, Bishoftu and Jijiga, with LCRPGR index 0.53 and 3.65 respectively, were the highest and the lowest in terms of land use efficiencies (Fig. 6). Out of ten cities, only three managed to score LCRPGR score ≤1, which shows efficient urban land use. The reaming seven cities have a LCRPGR score >1, which demonstrates low land use efficiency.

From 2007 to 2014 and 2014 to 2019, Jijiga and Bahir Dar were the two cities with the highest LCRPGR index, consecutively. That means, during this period; the two cities were the highest as far as land use inefficiencies are concerned. Bishoftu, with its 0.40 LCRPGR index, is the best in terms of land use efficiency from 2007 to 2014. Between 2014 and 2019, with its 0.85 LCRPGR index, Hawassa scored the highest level of land use efficiency (Fig. 6).

The average LCRPGR index for the year 2007–2014 and 2014–2019 were 1.40 and 1.80, respectively. That means land use efficiency during these periods was low.

4.1.4. Urban densification

In most of the regional cities, the proportion of the built-up area is not optimal. In 2019, except Hawassa, for the rest of the cities, the ratio of built-up area is less than 70%. In fact, the built-up area makes up 37% and 39% of Bishoftu and Bahir Dar, respectively. In Mekele and Jijiga, the built-up area is around 50% of the total area (Table 2). Vegetation cover and open spaces constitute a significant part of the built-up environment in all the cities studied.

From 2007 to 2019, significant densification (urban infill) occurred in the regional cities. Eight regional cities scored average densification of 184%. Jijiga's densification, with 507%, is exceptionally high. Adama, with 58% of densification, was the lowest (Fig. 7).

4.2. Land use efficiency in Addis Ababa's satellite cities

4.2.1. Built-up area expansion

Addis Ababa satellite cities have been among the fastest-growing urban centres in Ethiopia. The built-up area footprint of these cities witnessed a vast expansion over the past two decades. From 2007 to 2019, for instance, Sebeta's built-up area expanded by about 93%. During the same period, Burayu, Sululta and Dukem expanded by 500%, 1750% and 300%, respectively. From 2010 to 2019, Legetafo and Gelan's built-up area footprint grew by around 109% and 59%, consecutively. In all cities, the biggest urban expansion occurred between 2007 and 2014 (Table 3).

4.2.2. LCRPGR index of Sebeta, Burayu and Sululta

Between 2007 and 2019, Sebeta, Burayu and Sululta had LCRPGR index of 1.11, 3.02 and 2.62, correspondingly. For these cities, the level of land use inefficiency was much higher from 2007 to 2014. During this period, Sebeta, Burayu and Sululta's LCRPGR index were 1.45, 4.58 and 4.74, respectively.[11] However, from 2014 to 2019; the LCRPGR index of the cities was <1, which shows efficient land use (Fig. 8).

4.2.3. Urban densification

Though it is low, densification is also taking place in Addis Ababa satellite cities. For example, until the end of 2019, the built-up area constituted about 51%, 41%, 28% and 35% of Legetafo, Sulults, Gelan and Dukem, consequently (Fig. 9). The rest is made up of vegetation cover and open spaces (Fig. 10). At the same time, urban boundaries kept further expanding into peri-urban areas.

Most of the cities, in general, rapidly expanded outward while a significant part of buildable land existed within the existing built-up area. Urban boundaries not only expanded deep into farmlands but also in a fragmented way. This substantially increased built-up area footprint while contributing very little to improve densification.

4.3. Land use efficiency: residential vs industrial land uses

Google Earth imagery analysis of four cities (Hawassa, Dukem, Sululta and Bahir Dar) reveals that, between 2009 and 2019, the degree of land utilization is not the same for all urban land use types. Though land use inefficiency is prevalent among all land use types, in almost all the cities investigated, land allocated for residential purposes has been developed and used productively as compared to land transferred for

[11] LCRPGR index of Dukem, Gelan and Legetafo is not included due to lack of reliable population data.

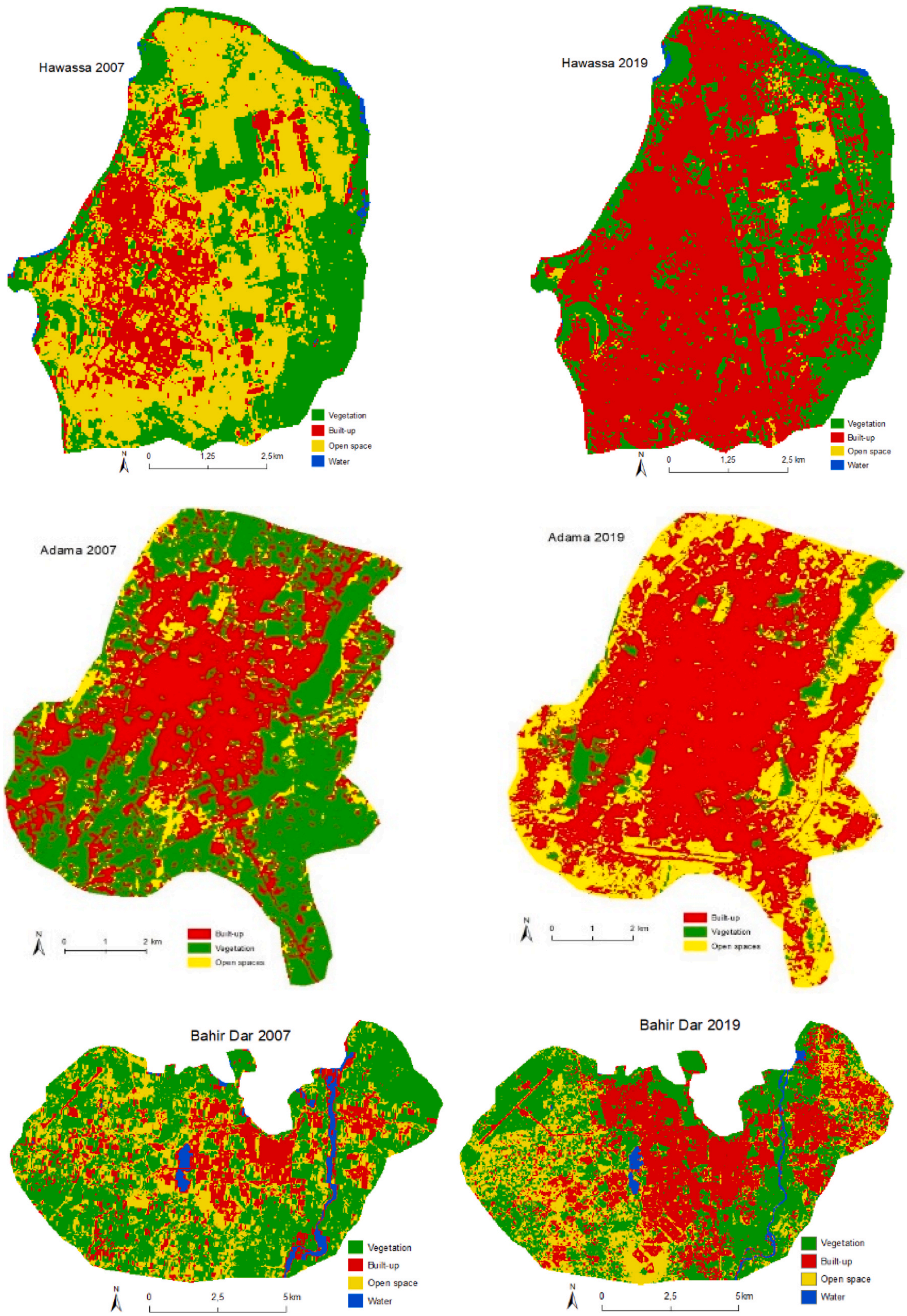

Fig. 2. Built-up footprint expansion of Hawassa, Adama and Bahir Dar (2007–2019).

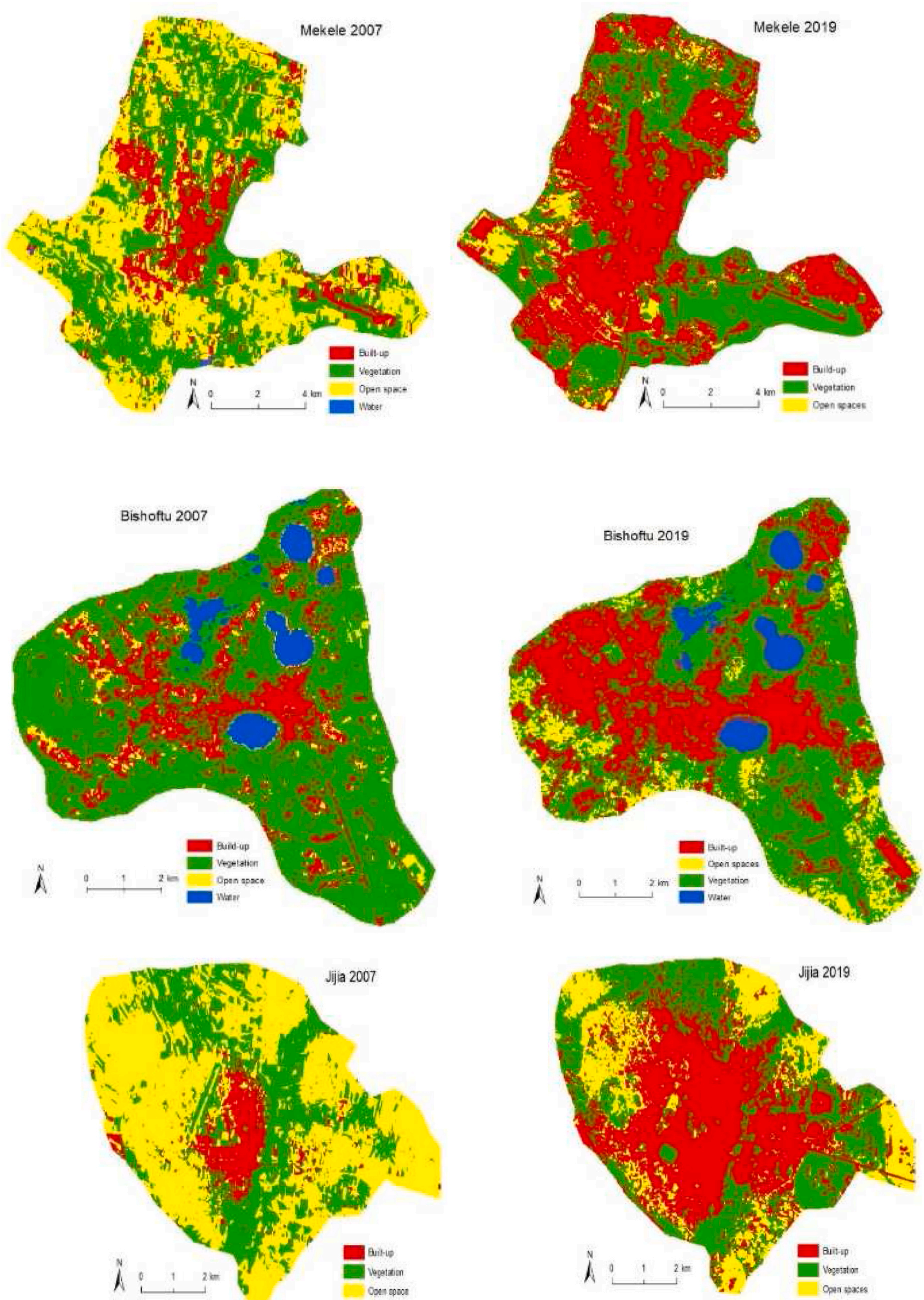

Fig. 3. Built-up area footprint expansion of Mekele, Bishoftu and Jijiga (2007–2019).

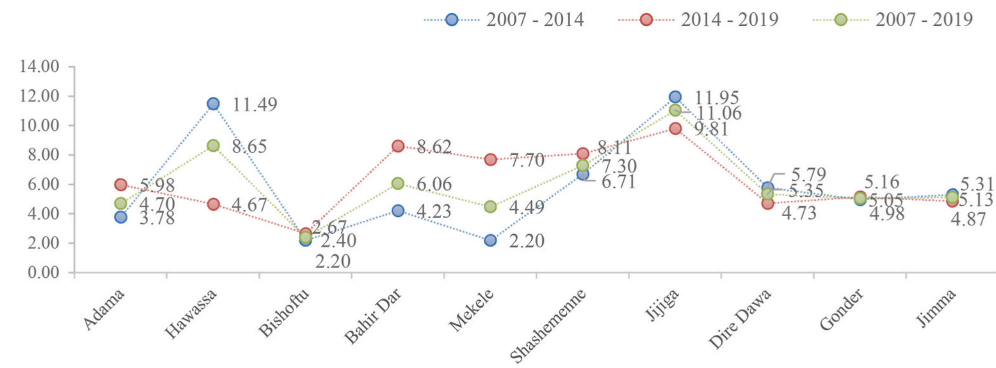

Fig. 4. LCR of the regional cities.

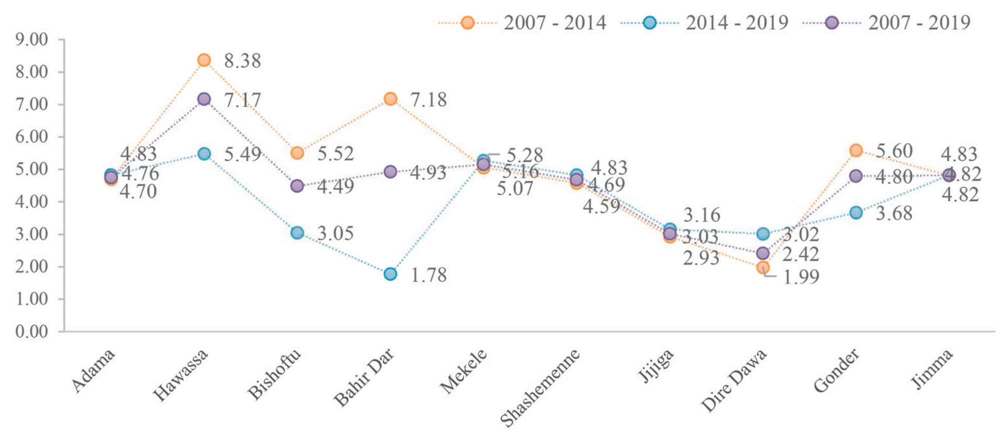

Fig. 5. PGR of the regional cities.

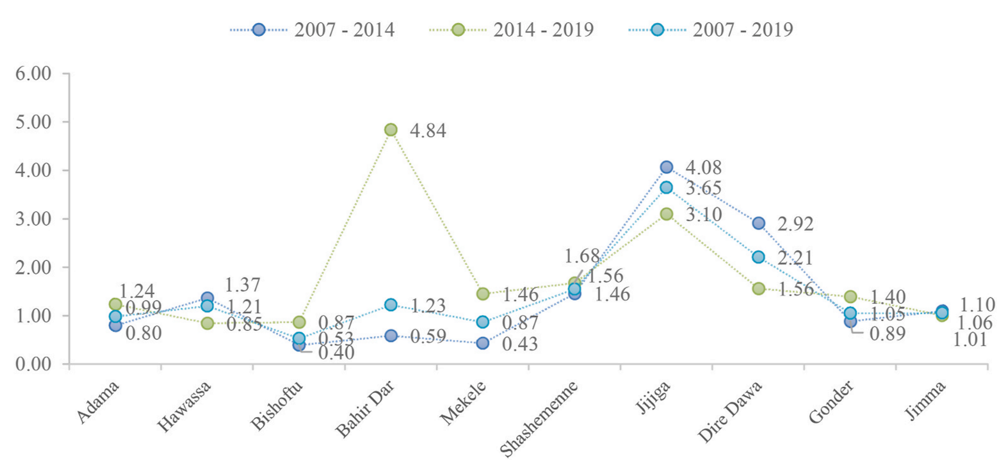

Fig. 6. LCRPGR index of the regional cities.

Table 2
Percentage of land cover types in regional cities in 2019.

	Adama	Hawassa	Bishoftu	Bahir Dar	Mekele	Shashemenne	Jijiga	Gonder
Built-up	63	74	37	39	52	46	50	48
Vegetation	7	25	50	56	41	51	5	7
Open spaces	30	1	8	3	7	3	45	45
Water	0	0	5	2	0	0	0	0

industrial uses (including real estate development) (Fig. 11). Big size plots meant for industrial (investment) purposes, mainly in prime locations, sit in their entirety or a significant part of it vacant for years.

5. Discussion

The results of the study reveal that between 2007 and 2019, most of

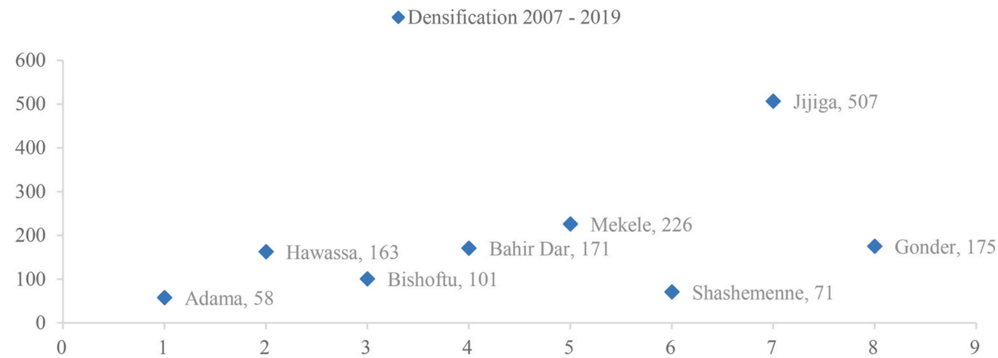

Fig. 7. Urban densification (infill) in % (2007–2019).

Table 3
Built-up area of Addis Ababa satellite cities (sq.km).

	Sebeta	Burayu	Sululta	Dukem		Gelan	Legetafo
2007	30	13	2	5	2010	9	11
2014	49	61	25	17	2014	12	20
2019	58	78	37	20	2019	14	23

the cities' built-up area footprint expanded enormously. Apart from Bishoftu, Gelan and Mekele, the rest of the cities expanded by over 70% during this period. Regional cities and Addis Ababa satellite cities grew by an average of 115% and 438%, respectively. Addis Ababa satellite cities, smaller and relatively new, expanded faster than the regional cities.

The study discovers that in seven regional cities, out of ten, the LCR is higher than the PGR. Three of Addis Ababa's satellite cities, where LCRPGR was analysed, witnessed higher LCR than PGR. However, the level of LCR, PGR and LCRPGR index was not the same across the cities, particularly for the regional cities. Some cities experienced cases of very high LCR, which sometimes is more than twice the PGR. Hence, resulting in a high LCRPGR index in a couple of cities. This reveals the prevalence of high urban land use inefficiencies. Bishoftu (despite its proximity to Addis Ababa) and Mekele (despite its size) had a better land use efficiency record. There is no obvious reason for this. Nevertheless, this might have something to do with moderately good practices of urban planning and land management.

On the other hand, the LCR and PGR of the cities were not uniform across the temporal dimension. Some cities experienced a fast rate of LCR between 2007 and 2014. Others witnessed a notable expansion after 2014. A significant spike in LCR, while PGR is very low, might indicate of state or non-state actors rush to capture peri-urban land. Similarly, the LCRPGR index of the cities, a measure of urban land use efficiency, was also different for the different periods. Most of the regional cities experienced high LCRPGR between 2014 and 2019. On the contrary, the LCRPGR index of Addis Ababa's satellite cities was higher between 2007 and 2014. This might indicate rapid urbanization and massive rural land conversion in Addis Ababa and its surrounding before the spillover effect reached the regional cities.

Urban land use efficiency is low in most of Ethiopia's cities. With its 1.2 LCRPGR index, Addis Ababa's urban land efficiency is lower when compared with its counterparts in the region: Nairobi (0.9), Dar es Salaam (0.2), Khartoum (0.9), Kampala (0.4) and Kigali (0.6) (Melchiorri et al., 2019). Likewise, Ethiopia's regional cities score low in ULUE when compared with cities at the same level in Eastern Africa. Globally, land use efficiency index of $0 < \text{LCRPGR} < 1$, $1 < \text{LCRPGR} < 2$ and $\text{LCRPGR} > 2$ accounts for 39%, 20% and 22%, respectively (Melchiorri et al., 2019). In Ethiopia, 70% of the regional cities investigated have an LCRPGR index of >1. This shows that the ULUE of Ethiopian cities is much higher than the global average. Low land use efficiency has ramifications on land and housing prices, infrastructure provision, economic agglomeration, informal settlement, etc (Guida-Johnson et al., 2017; Hommann & Lall, 2019; UN-Habitat, 2020a; World Bank, 2020b).

The findings confirm that in almost all cities studied, a significant size of developable land sits idle within the built-up area. In 2019, in all the cities, the built-up area percentage is less than 70%. In this regard, the only exception is Hawassa. Bishoftu, Bahir Dar, Sululta, Dukem and Gelan's built-up area represents less than 50%. The rest is a combination

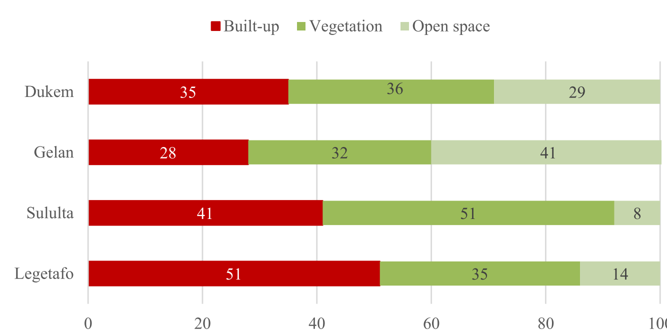

Fig. 9. Built-up density of Addis Ababa satellite cities 2010–2019.

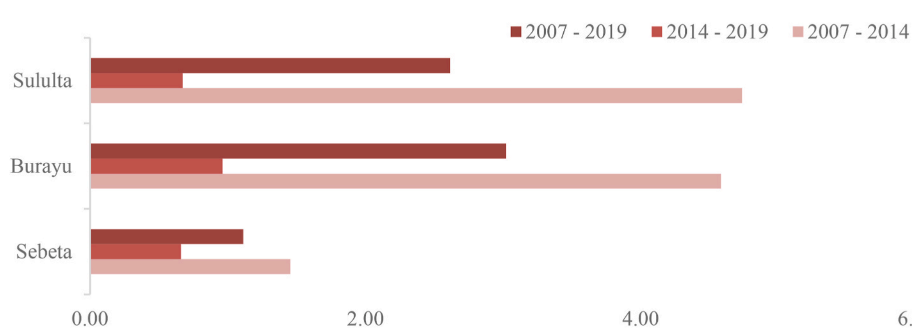

Fig. 8. LCRPGR index of three Addis Ababa satellite cities.

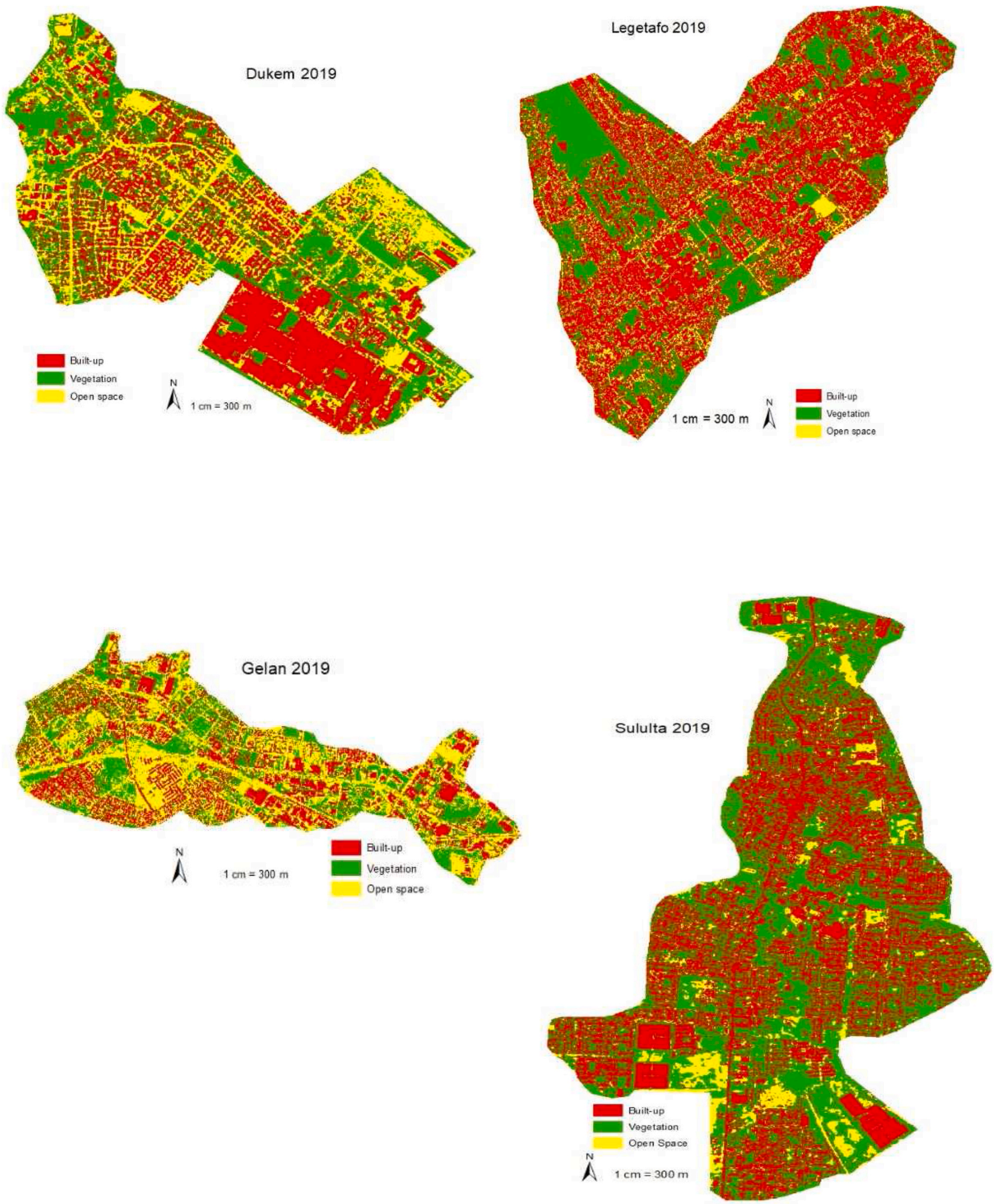

Fig. 10. City proper built-up density of Addis Ababa satellite cities.

of vegetation cover, open spaces, and water. Densification is taking place in all cities. On the other hand, a high percentage of densification underlines the existence of substantial size of vacant land within the built-up environment. This reveals gaps in urban planning and implementation. Furthermore, it confirms flaws in land management and urban sprawl control. Converted lands should have been used efficiently before embarking on outward expansion. Even though densification has been steadily going on, the cities continuously expanded outward while a substantial size of buildable land exists within the built-up environment. This finding is in line with the World Bank (2015) and ICF International Ltd. et al. (2019) findings. In fact, for most cities, the rate of boundary expansion is higher than densification. The World Bank study claimed, "Ethiopian cities have vacant or under-used land in prime locations, which could be leveraged for denser and more contiguous

Fig. 11. Land use efficiency: Residential (outside yellow) vs industrial (inside yellow) land uses. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

development in existing urban areas" (World Bank, 2015: p: 54). Underdeveloped land accounts for 46%, 25%, 77% and 32% of Mekele, Bahir Dar, Dessie and Hawassa, subsequently. Boundary expansion, according to the World Bank, is not a response to "accommodate actual population growth". Rather, it is mainly driven by the perception of a shortage of land inside the cities, though that is not the case.

Land use inefficiency is pervasive across the cities. The level of land use inefficiency, nevertheless, varies based on land use types. For instance, land allocated for industrial (investment) purposes is the ones disproportionately fenced or underutilized. There is an obvious pattern that shows that land allocated for industrial uses, usually in prime locations, remains fully or partially vacant for years. Industrial land use exhibited a high level of land use inefficiency expressed in terms of urban land vacancy (low land use density and utilization). However, a close investigation showed that many empty residential plots sit idle within relatively developed residential areas as well. Even though a substantial size of land sits idle in Addis Ababa, 57% (2002) and 26% (2011) of businesses believe that access to land is one of the major hurdles to do business in Ethiopia (Ozlu et al., 2015). These figures are high even by African standard, and it contradicts the country's land policy objectives. Challenges like these happened despite huge farmland conversion and the cities' boundary expansion. The underlying problem might be caused by issues pertinent to land hoarding and land banking, which affect supply and demand.

The purpose of this study is to investigate urban land use efficiency in various cities in Ethiopia. The findings reveal that there is a widespread urban land use inefficiency in almost all the cities included in the study. The state of Ethiopian cities, regarding ULUE, is very much similar to what other African cities are experiencing. Land use inefficiency has become a defining feature of many African cities (Lall et al., 2017). It is common to see patches of undeveloped land in African cities. In Africa, according to (Lall et al., 2017), cities are expanding in a fragmented way. Besides, African cities are 23% more fragmented than either Latin American or Asian cities (Henderson and Nigmatulina 2016). In general, urban sprawl is pervasive across African cities. This is posing challenges related to connectivity, infrastructure cost, food security, etc. (AfDB/OECD/UNDP, 2016). Because of low land use efficiency, which resulted in land fragmentation, African cities become costly to live in and do business (Lall et al., 2017).

According to various studies, there are multiple factors responsible for urban land use inefficiencies. The overlapping and unrealistic regulatory framework not only makes policy implementation difficult but also pushes people to urban peripheries where they build homes informally fuelling urban sprawl (Lall et al., 2017; OECD/PSI, 2020; Page, Gutman, Madden, & Gandhi, 2020; World Bank Group, 2015). Lack of capacity to plan and manage urban land and institutional weakness to enforce policies leads to inefficient land use (Bandauko, Annan-Aggrey, & Arku, 2021; Lall et al., 2017; UCLGA/Cities Alliance, 2018; World Bank, 2014, 2020b; World Bank Group, 2021). Using land as a source of municipal revenue incentivised excessive land conversion (UN-Habitat, 2020a; Wang, Shao, Wang, & Wu, 2021; Wang, Huang, et al., 2020; World Bank, 2020b). In countries such as China, Ethiopia and Vietnam, land oversupply to attract investments affected land use efficiency (Koroso et al., 2020; Liu, Fan, Yue, & Song, 2018; OECD, 2015). Unaffordable housing and land price forced people to move to the urban fringes where land price is lower (Lall, Lebrand, Park, Sturm, & Venables, 2021; OECD, 2018; UN-Habitat, 2020a; Wang, Huang, et al., 2020). In Vietnam, for instance, informal settlements are catering for the urban poor. Land hoarding, which resulted in a considerable size of idle land, has contributed to ULUE (Koroso et al., 2020; OECD, 2015; World Bank, 2020b). Experiences from China, Vietnam and Ethiopia showed that below market price land supply for investment resulted in land hoarding for speculative purposes. In Accra, Ghana, land speculation inflated urban expansion into peri-urban lands (Korah, Matthews, & Tomerini, 2019). It seems that most of these factors contributed to the low ULUE exhibited in the study areas.

The findings of this study contribute significantly to understanding the magnitude of the challenges in areas pertinent to urban land use efficiency. Understanding the status of urban land use efficiency in Ethiopia is imperative to pursue policies aimed at ensuring sustainable land use; addressing land prices and housing shortages; protecting farmland and the environment; tackling land hoarding, urban sprawl and informal settlements. This research makes a significant contribution to filling gaps in these areas. The results of the study are relevant for countries with similar urban land policies (state land ownership); for developing countries, especially Sub-Saharan Africa, experiencing rapid urbanization and grappling with urban planning and land management issues because of institutional and capacity constraints.

This study has some limitations. These limitations are due to financial, time, technical and data availability constraints. First, the study focused mainly on remote sensing data to assess land use efficiency in the study areas. Empirical and socio-economic data are lacking. Second, despite fast urbanization that affected several cities across the country, the study focused on a number of cities. Some regional cities were not included. Third, this study did not address the underlying reasons behind land use inefficiencies and ways to deal with them. This requires further investigation. Finally, the lack of reliable population data inhibited rigorous ULUE analysis, mainly for Addis Ababa satellite cities. This is specifically the case for Dukem, Gelan and Legetafo.

6. Conclusion

This study focused on assessing land use efficiency in regional and Addis Ababa's satellite cities in Ethiopia. We mainly focused on remote sensing data to assess land use efficiency in the study areas. It is apparent from the study that there are pervasive practices of land use inefficiency. In almost all the cities investigated, the rate of land consumption outpaced the rate of population growth. Urban boundaries expanded rapidly. This happened while substantial land sits idle within the built-up areas.

Although all land use types have been inefficiently used, land allocated for industrial uses is the most underutilized across the cities. Sometimes, the land has been fenced for years with no sign of development. In areas where development projects have been commenced, it is far from optimal or complete.

There is steady densification in the cities, principally in the inner sections. The total built-up density remains low, nonetheless. In some cities, in contrast, density is gradually decreasing because of the expansion of built-up area footprint and the pervasive practices of land hoarding.

The land is an engine of economic development and urbanization. Sustainable urbanization and economic development cannot be guaranteed without efficient use of urban land. Therefore, urban growth should focus on efficient and sustainable land use rather than following a path of insatiable land consumption and boundary expansion. Continuous and massive expansion is not tenable. To improve land use efficiency in urban areas, land use efficiency needs to be given due attention. The focus should be on developing the under-utilized land inside the built-up environment. In order to realize this, so far, land lease policy provisions on efficient land utilization seem to have been largely ignored. This needs to be addressed for the country to improve practices of urban land use. Because ensuring efficient land use not only improves land utilization but also helps to reduce infrastructure costs, curtail informal settlements, stabilize land prices and housing shortages. It will also help limit farmland conversion and minimize impacts on ecosystems.

In general, it may be prudent to take multiple measures to improve land use efficiency. First, the current land lease policy should be properly enforced. Second, policy gaps that have created loopholes for inefficient land use need to be reviewed. Finally, municipalities should put additional measures in place to tackle land hoarding and land mismanagement. Above all, the country needs to review its approach to urban land utilization and have sustainable urban land use policies to improve urban land use efficiency and achieve the UN SDG 11.3.

Author statement

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2. Monica Lengoiboni: Supervision, Reviewing and Editing.
3. Jaap Zevenbergen: Supervision, Reviewing and Editing.

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References

Abebe, M. T., & Megento, T. L. (2016). The city of addis ababa from 'forest city' to 'urban heat island': Assessment of urban green space dynamics. *Journal of Urban and Environmental Engineering, 10*(2), 254–262. https://doi.org/10.4090/juee.2016.v10n2.254262

Adam, A. G. (2014). Informal settlements in the peri-urban areas of Bahir Dar, Ethiopia: An institutional analysis. *Habitat International, 43*, 90–97. https://doi.org/10.1016/j.habitatint.2014.01.014

Admasu, W. F., Van Passel, S., Minale, A. S., Tsegaye, E. A., Azadi, H., & Nyssen, J. (2019). Take out the farmer: An economic assessment of land expropriation for urban expansion in Bahir Dar, Northwest Ethiopia. *Land Use Policy, 87*. https://doi.org/10.1016/j.landusepol.2019.104038

Ambaye, D. W. (2015). *Land rights and expropriation in Ethiopia*. Springer International Publishing.

Azagew, S., & Worku, H. (2020). Accessibility of urban green infrastructure in addis-ababa city, Ethiopia: Current status and future challenge. *Environmental Systems Research, 9*(1), 26. https://doi.org/10.1186/s40068-020-00187-0

Bagan, H., & Yamagata, Y. (2012). Landsat analysis of urban growth: How Tokyo became the world's largest megacity during the last 40 years. *Remote Sensing of Environment, 127*, 210–222. https://doi.org/10.1016/J.RSE.2012.09.011

Bakker, V., Verburg, P. H., & van Vliet, J. (2021). Trade-offs between prosperity and urban land per capita in major world cities. *Geography and Sustainability, 2*(2), 134–138. https://doi.org/10.1016/J.GEOSUS.2021.05.004

Bandauko, E., Annan-Aggrey, E., & Arku, G. (2021). Planning and managing urbanization in the twenty-first century: Content analysis of selected african countries' national urban policies. *Urban Research & Practice, 14*(1), 94–104. https://doi.org/10.1080/17535069.2020.1803641

Cai, G., Zhang, J., Du, M., Li, C., & Peng, S. (2020). Identification of urban land use efficiency by indicator-SDG 11.3.1. *PloS One, 15*(12), Article e0244318. https://doi.org/10.1371/journal.pone.0244318

Chen, Y., Chen, Z., Xu, G., & Tian, Z. (2016). Built-up land efficiency in urban China: Insights from the general land use plan (2006–2020). *Habitat International, 51*, 31–38. https://doi.org/10.1016/j.habitatint.2015.10.014

Claassens, J., & Koomen, E. (2018). Are current cities dense enough? A case study for The Netherlands. *58th congress of the European regional science Association : Places for people*. Retrieved from https://research.vu.nl/en/publications/are-current-cities-dense-enough-a-case-study-for-the-netherlands/fingerprints/.

Corbane, C., Politis, P., Siragusa, A., Kemper, T., & Pesaresi, M. (2017). *LUE user guide: A tool to calculate the land use efficiency and the SDG 11.3 indicator with the global human settlement layer*. https://doi.org/10.2760/212689

Dadi, D., Azadi, H., Senbeta, F., Abebe, K., Taheri, F., & Stellmacher, T. (2016). Urban sprawl and its impacts on land use change in Central Ethiopia. *Urban Forestry and Urban Greening, 16*, 132–141.

D'Amour, C. B., Reitsma, F., Baiocchi, G., Barthel, S., Güneralp, B., Erb, K. H., et al. (2017). Future urban land expansion and implications for global croplands. *Proceedings of the National Academy of Sciences of the United States of America, 114*, 8939–8944. https://doi.org/10.1073/pnas.1606036114. August 22.

Danni, Z. (2019). Land use efficiency and its change of Vietnam based on DEA. *IOP Conference Series: Earth and Environmental Science, 310*(5). https://doi.org/10.1088/1755-1315/310/5/052063

Du, J., & Peiser, R. B. (2014). Land supply, pricing and local governments' land hoarding in China. *Regional Science and Urban Economics, 48*, 180–189.

Duque, J. C., Lozano-Gracia, N., Patino, J. E., & Restrepo, P. (2019). Urban form and Productivity : What is the shape of Latin American Cities ?. In *Urban form and productivity: What is the shape of Latin American cities?*. https://doi.org/10.1596/1813-9450-8697

Estoque, R. C., Ooba, M., Togawa, T., Hijioka, Y., & Murayama, Y. (2021). Monitoring global land-use efficiency in the context of the UN 2030 Agenda for Sustainable Development. *Habitat International, 115*, 102403. https://doi.org/10.1016/J.HABITATINT.2021.102403

Fenta, A. A., Yasuda, H., Haregeweyn, N., Belay, A. S., Hadush, Z., Gebremedhin, M. A., et al. (2017). The dynamics of urban expansion and land use/land cover changes using remote sensing and spatial metrics: The case of mekelle city of northern Ethiopia. Http://Dx.Doi.Org/10.1080/01431161.2017.1317936 https://doi.org/10.1080/01431161.2017.1317936, 38(14), 4107-4129.

Forget, Y., Shimoni, M., Gilbert, M., & Linard, C. (2021). Mapping 20 Years of urban expansion in 45 urban areas of sub-saharan Africa. *Remote Sensing, 13*(3), 525. https://doi.org/10.3390/rs13030525

Gabriel, S. A., Faria, J. A., & Moglen, G. E. (2006). A multiobjective optimization approach to smart growth in land development. *Socio-Economic Planning Sciences, 40*(3), 212–248. https://doi.org/10.1016/j.seps.2005.02.001

Gao, X., Zhang, A., & Sun, Z. (2020). How regional economic integration influence on urban land use efficiency ? A case study of Wuhan metropolitan area, China. *Land Use Policy, 90*. https://doi.org/10.1016/j.landusepol.2019.104329

Gemeda, B. S., Abebe, B. G., Paczoski, A., Xie, Y., & Cirella, G. T. (2019). What motivates speculators to speculate? *Entropy, 22*(1), 59. https://doi.org/10.3390/e22010059

Girma, Y., Terefe, H., & Pauleit, S. (2019). Urban green spaces use and management in rapidly urbanizing countries:-The case of emerging towns of Oromia special zone surrounding Finfinne, Ethiopia. *Urban Forestry and Urban Greening, 43*. https://doi.org/10.1016/j.ufug.2019.05.019

Global Platform for Sustainable Cities. (2018). Urban sustainability framework. In *Urban sustainability framework*. https://doi.org/10.1596/29364

Goldblatt, R., Deininger, K., & Hanson, G. (2018). Utilizing publicly available satellite data for urban research: Mapping built-up land cover and land use in Ho Chi Minh City, Vietnam. *Development Engineering, 3*, 83–99. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2352728517300842.

Gong, J., Hu, Z., Chen, W., Liu, Y., & Wang, J. (2018). Urban expansion dynamics and modes in metropolitan Guangzhou, China. *Land Use Policy, 72*, 100–109.

Guida-Johnson, B., Faggi, A. M., & Zuleta, G. A. (2017). Effects of urban sprawl on riparian vegetation: Is compact or dispersed urbanization better for biodiversity? *River Research and Applications, 33*(6), 959–969. https://doi.org/10.1002/rra.3138

Ha, V. T., & Nguyen, H. N. (2019). Urbanization and challenges to sustainable urban land development in the Ho chi minh city metropolitan area. *Urbana, 20*, 24–33.

Han, X., Zhang, A., & Cai, Y. (2020). Spatio-econometric analysis of urban land use efficiency in China from the perspective of natural resources input and undesirable outputs: A case study of 287 cities in China. *International Journal of Environmental Research and Public Health 2020, 17*(19), 7297. https://doi.org/10.3390/IJERPH17197297. Page 7297, 17.

Haščič, I., & Mackie, A. (2018). Land cover change and conversions: Methodology and results for OECD and G20 countries. In *OECD green growth papers* (No. 2018). Retrieved from https://www.oecd-ilibrary.org/environment/land-cover-change-and-conversions_72a9e331-en.

Hepinstall-Cymerman, J., Coe, S., & Hutyra, L. R. (2013). *Urban growth patterns and growth management boundaries in the Central Puget Sound, Washington, 1986-2007. Urban Ecosystems* (Vol. 16, pp. 109–129). https://doi.org/10.1007/s11252-011-0206-3

Hommann, K., & Lall, S. V. (2019). Which way to livable and productive cities? *Which Way to Livable and productive cities?: A road Map for sub-saharan Africa*. https://doi.org/10.1596/978-1-4648-1405-1.

Huang, J., & Xue, D. (2019). Study on temporal and spatial variation characteristics and influencing factors of land use efficiency in Xi'an, China. *Sustainability, 11*(23). https://doi.org/10.3390/su11236649

Hu, J., Wang, Y., Taubenböck, H., & Zhu, X. X. (2021). Land consumption in cities: A comparative study across the globe. *Cities, 113*, 103163. https://doi.org/10.1016/J.CITIES.2021.103163

Hu, Q., Wu, W., Xia, T., Yu, Q., Yang, P., Li, Z., et al. (2013). Exploring the use of Google Earth imagery and object-based methods in land use/cover mapping. *Remote Sensing, 5*(11), 6026–6042.

Jiao, L., Xu, Z., Xu, G., Zhao, R., Liu, J., & Wang, W. (2020). Assessment of urban land use efficiency in China: A perspective of scaling law. In *Habitat international* (Vol. 99). https://doi.org/10.1016/j.habitatint.2020.102172

Kleemann, J., Inkoom, J. N., Thiel, M., Shankar, S., Lautenbach, S., & Fürst, C. (2017). Peri-urban land use pattern and its relation to land use planning in Ghana, West Africa. *Landscape and Urban Planning, 165*, 280–294. https://doi.org/10.1016/j.landurbplan.2017.02.004

Korah, P. I., Matthews, T., & Tomerini, D. (2019). Characterising spatial and temporal patterns of urban evolution in Sub-Saharan Africa: The case of Accra, Ghana. *Land Use Policy, 87*, 104049. https://doi.org/10.1016/j.landusepol.2019.104049

Koroso, N. H., Zevenbergen, J. A., & Lengoiboni, M. (2019). Land institutions' credibility: Analyzing the role of complementary institutions. *Land Use Policy, 81*, 553–564. https://doi.org/10.1016/j.landusepol.2018.11.026

Koroso, N. H., Zevenbergen, J. A., & Lengoiboni, M. (2020). Urban land use efficiency in Ethiopia: An assessment of urban land use sustainability in Addis Ababa. *Land Use Policy, 99*, 105081. https://doi.org/10.1016/j.landusepol.2020.105081

Lall, S. V., Henderson, J. V., & Venables, A. J. (2017). In *Africa's cities: Opening doors to the world*. https://doi.org/10.1596/978-1-4648-1044-2

Lall, S., Lebrand, M., Park, H., Sturm, D., & Venables, A. (2021). *Pancakes to Pyramids : City form to promote sustainable growth*. Washington, DC website: Retrieved from World Bank. https://openknowledge.worldbank.org/handle/10986/35684.

Lambin, E. F., & Meyfroidt, P. (2011). March 1). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 3465–3472. https://doi.org/10.1073/pnas.1100480108

Larsen, L., Yeshitela, K., Mulatu, T., Seifu, S., Desta, H., Larsen, L., et al. (2019). The impact of rapid urbanization and public housing development on urban form and density in addis ababa, Ethiopia. *Land, 8*(4), 66.

Lin, G. C. S. S., & Ho, S. P. S. S. (2005). *The state, land system, and land development processes in contemporary China* (Vol. 95). Annals of the Association of American Geographers §.

Liu, Y., Fan, P., Yue, W., & Song, Y. (2018). Impacts of land finance on urban sprawl in China: The case of Chongqing. *Land Use Policy, 72*, 420–432. https://doi.org/10.1016/J.LANDUSEPOL.2018.01.004

Liu, S., Ye, Y., & Li, L. (2019). Spatial-temporal analysis of urban land-use efficiency: An analytical framework in terms of economic transition and spatiality. *Sustainability, 11*(7). https://doi.org/10.3390/su11071839
Li, X., Zhou, W., & Ouyang, Z. (2013). Forty years of urban expansion in Beijing: What is the relative importance of physical, socioeconomic, and neighborhood factors? *Applied Geography, 38*, 1–10.
Lu, X., Chen, D., Kuang, B., Zhang, C., & Cheng, C. (2020). Is high-tech zone a policy trap or a growth drive? Insights from the perspective of urban land use efficiency. *Land Use Policy, 95*. https://doi.org/10.1016/j.landusepol.2020.104583
Lustgarten, A. (2020). The great climate migration has begun. Retrieved july 31, 2021, from the New York times website. https://www.nytimes.com/interactive/2020/07/23/magazine/climate-migration.html.
Malarvizhi, K., Kumar, S. V., & Porchelvan, P. (2016). Use of high resolution Google Earth satellite imagery in landuse map preparation for urban related applications. *Procedia Technology, 24*, 1835–1842.
Melchiorri, M., Pesaresi, M., Florczyk, A., Corbane, C., & Kemper, T. (2019). Principles and applications of the global human settlement layer as baseline for the land use efficiency indicator—SDG 11.3.1. *ISPRS International Journal of Geo-Information, 8*(2), 96. https://doi.org/10.3390/ijgi8020096
Mengistu, F., & van Dijk, M. P. (2018). Credibility of institutions in Addis Ababa (Ethiopia), effects of government policies on real estate developers. *Land Use Policy, 79*, 913–921. https://doi.org/10.1016/j.landusepol.2016.12.031
Mudau, N., Mwaniki, D., Tsoeleng, L., Mashalane, M., Beguy, D., & Ndugwa, R. (2020). Assessment of SDG indicator 11.3.1 and urban growth trends of major and small cities in South Africa. *Sustainability, 12*(17). https://doi.org/10.3390/su12177063
Nicolau, R., David, J., Caetano, M., & Pereira, J. M. C. (2019). Ratio of land consumption rate to population growth rate-analysis of different formulations applied to mainland Portugal. *ISPRS International Journal of Geo-Information, 8*(1). https://doi.org/10.3390/ijgi8010010
van Noorloos, F., & Kloosterboer, M. (2018). Africa's new cities: The contested future of urbanisation. *Urban Studies, 55*(6), 1223–1241. https://doi.org/10.1177/0042098017700574
OECD. (2015). OECD urban policy reviews: China. https://doi.org/10.1787/9789264230040-EN (p. 244). p. 244.
OECD. (2018). Rethinking urban Sprawl : Moving towards sustainable cities. https://doi.org/10.1787/9789264189881-en.
OECD. (2020a). Africa's urbanisation dynamics 2020: Africapolis, mapping a new urban geography. Retrieved from https://www.oecd-ilibrary.org/content/publication/b6bccb81-en.
OECD. (2020b). Africa's urbanisation dynamics 2020: Africapolis, mapping a new urban geography sahel and west Africa club. https://doi.org/10.1787/B6BCCB81-EN.
OECD/PSI. (2020). Rural development strategy review of Ethiopia: Reaping the benefits of urbanisation. https://doi.org/10.1787/A325A658-EN.
Ozlu, M. O., Alemayehu, A., Mukim, M., Lall, S. V., Kerr, O. T., Kaganova, O., et al. (2015). *Ethiopia urbanization Review : Urban institutions for a middle-income Ethiopia* (Vol. 58). https://doi.org/10.1128/AAC.03728-14
Page, J., Gutman, J., Madden, P., & Gandhi, D. (2020). *Urban economic growth in Africa A framework for analyzing constraints to agglomeration*.
Pelczynski, J., & Tomkowicz, B. (2019). Densification of cities as a method of sustainable development. *IOP Conference Series: Earth and Environmental Science, 362*(1). https://doi.org/10.1088/1755-1315/362/1/012106
Saghir, J., & Santoro, J. (2018). Urbanization in sub-saharan Africa: Meeting challenges by bridging stakeholders. Retrieved from https://en.oxforddictionaries.com/definition/sharing_economy.
Schmidt, E., Dorosh, P., Jemal, M. K., & Smart, J. (2018). Ethiopia's spatial and structural transformation: Public policy and drivers of change. https://doi.org/10.2499/1046080775.
Shao, Z., Sumari, N. S., Portnov, A., Ujoh, F., Musakwa, W., & Mandela, P. J. (2020). Urban sprawl and its impact on sustainable urban development: A combination of remote sensing and social media data. *Geo-Spatial Information Science*, 1–15. https://doi.org/10.1080/10095020.2020.1787800
Steel, G., Abukashawa, S., & Hussein, M. O. (2020). Urban transformations and land governance in peri-urban Khartoum: The case of soba. *Tijdschrift voor Economische en Sociale Geografie, 111*(1), 45–59. https://doi.org/10.1111/tesg.12372
Terfa, B. K., Chen, N., Liu, D., Zhang, X., Niyogi, D., Terfa, B. K., et al. (2019). Urban expansion in Ethiopia from 1987 to 2017: Characteristics, spatial patterns, and driving forces. *Sustainability, 11*(10), 2973.
Terfa, B. K., Chen, N., Zhang, X., & Niyogi, D. (2020). Urbanization in small cities and their significant implications on landscape structures: The case in Ethiopia. *Sustainability, 12*(3). https://doi.org/10.3390/su12031235
Tian, L., Ge, B., & Li, Y. (2017). Impacts of state-led and bottom-up urbanization on land use change in the peri-urban areas of Shanghai: Planned growth or uncontrolled sprawl? *Cities, 60*, 476–486.
UCLGA/Cities Alliance. (2018). Assessing the institutional environment of local governments in Africa 2018, 3 th edition. Retrieved from. www.uclga.org.
UK Office for National Statistics. (2018). Using innovative methods to report against the sustainable development goals. Retrieved June 14, 2020, from https://www.ons.gov.uk/economy/environmentalaccounts/articles/usinginnovativemethodstoreportagainstthesustainabledevelopmentgoals/2018-10-22.
UN, D. E. S. A. (2019). World urbanization prospects: The 2018 revision. Retrieved from https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf.
UN ECOSOC. (2019). Special edition: Progress towards the sustainable development goals. Retrieved from https://undocs.org/E/2019/68.
UN-Habitat. (2018). SDG indicator 11.3.1 training module: Land use efficiency. Retrieved from https://urban-data-guo-un-habitat.hub.arcgis.com/datasets/indicator-11-3-1-training-module-land-consumption-jan-2019.
UN-Habitat. (2020a). The new urban Agenda. https://doi.org/10.18356/4665f6fb-en.
UN-Habitat. (2020b). Urban indicators database. Retrieved May 28, 2020, from UN-Habitat website. https://urban-data-guo-un-habitat.hub.arcgis.com/datasets/11-3-1-land-consumption-data-for-1990-2000-and-2015/data?page=76.
United Nation-HLPF, & UN. (2018). 2018 review of SDGs implementation: SDG 11 – make cities and human settlements inclusive, safe, resilient and sustainable. In *High-level political forum on sustainable development*. Retrieved from https://sustainabledevelopment.un.org/content/documents/197282018_background_notes_SDG_11_v3.pdf.
United Nations. (2015). Sustainable development goals. Retrieved May 21, 2020, from UN website: https://sustainabledevelopment.un.org/.
United Nations. (2017). New urban Agenda. Retrieved from www.habitat3.org.
UNSD. (2021). SDG indicator metadata. Retrieved July 14, 2021, from UNSD website: https://unstats.un.org/sdgs/metadata/files/Metadata-11-03-01.pdf.
Wang, S., Cebula, R. J., Liu, X., & Foley, M. (2020). *Housing prices and urban land use efficiency* (Vol. 28, pp. 1121–1124). https://doi.org/10.1080/13504851.2020.1803476. Https://Doi-Org.Proxy.Uba.Uva.Nl/10.1080/13504851.2020.1803476.
Wang, Y., Huang, C., Feng, Y., Zhao, M., & Gu, J. (2020). Using Earth observation for monitoring SDG 11.3.1-ratio of land consumption rate to population growth rate in mainland China. *Remote Sensing, 12*(3), 357. https://doi.org/10.3390/rs12030357
Wang, L., Li, H., & Shi, C. (2015). Urban land-use efficiency, spatial spillover, and determinants in China. *Dili Xuebao/Acta Geographica Sinica, 70*(11), 1788–1799. https://doi.org/10.11821/dlxb201511008
Wang, L., Li, C. C., Ying, Q., Cheng, X., Wang, X. Y., Li, X. Y., et al. (2012). China's urban expansion from 1990 to 2010 determined with satellite remote sensing. *Chinese Science Bulletin, 57*(22), 2802–2812. https://doi.org/10.1007/s11434-012-5235-7
Wang, P., Shao, Z., Wang, J., & Wu, Q. (2021). The impact of land finance on urban land use efficiency: A panel threshold model for Chinese provinces. *Growth and Change, 52*(1), 310–331. https://doi.org/10.1111/GROW.12464
Wang, X., Shen, X., & Pei, T. (2020). Efficiency loss and intensification potential of urban industrial land use in three major urban agglomerations in China. *Sustainability, 12*(4). https://doi.org/10.3390/su12041645
Wibowo, A., Salleh, K. O., Frans, F. T. R. S., & Semedi, J. M. (2016). Spatial temporal land use change detection using Google Earth data. *IOP Conference Series: Earth and Environmental Science, 47*(1), Article 012031. https://doi.org/10.1088/1755-1315/47/1/012031
World Bank. (2012). *Diagnosing corruption in Ethiopia: Perceptions, realities, and the way forward*. World Bank.
World Bank. (2014). *Addis Ababa urban and metropolitan transport and land use linkages strategy review*. Washington, DC website: Retrieved from World Bank. https://openknowledge.worldbank.org/handle/10986/26080.
World Bank. (2017). Safe and resilient cities in Ethiopia : City strength diagnostics in nine regional capitals and Dire Dawa city administration. In *Safe and resilient cities in Ethiopia*. https://doi.org/10.1596/32278
World Bank. (2020a). Ethiopia poverty assessment: Harnessing continued growth for accelerated poverty reduction. https://doi.org/10.1596/33544.
World Bank. (2020b). Vietnam's urbanization at a Crossroads : Embarking on an efficient, inclusive, and resilient pathway. In *Vietnam's urbanization at a crossroads*. https://doi.org/10.1596/34761
World Bank Group. (2015). *Addis Ababa, Ethiopia : Enhancing urban resilience*. Washington, DC website: Retrieved from World Bank. https://openknowledge.worldbank.org/handle/10986/23245.
World Bank Group. (2017). Reshaping urbanization in Rwanda : Urbanization and the evolution of Rwanda's urban landscape. In *Reshaping urbanization in Rwanda*. https://doi.org/10.1596/29081
World Bank Group. (2019). *Unlocking Ethiopia's urban land and housing Markets : Urban land supply and affordable housing study*. World Bank. https://doi.org/10.1596/32756 (No. 138371).
World Bank Group. (2021). *Demographic trends and urbanization*. Retrieved from Washington, DC website https://openknowledge.worldbank.org/handle/10986/35469.
Xing, Y., & Sun, L. (2013). Evaluation of the efficiency of land use in harbin based on DEA. ICCREM 2013: Construction and operation in the context of sustainability - proceedings of the 2013 international conference on construction and real estate management. https://doi.org/10.1061/9780784413135.143, 1456-1462.
Xu, G., Dong, T., Cobbinah, P. B., Jiao, L., Sumari, N. S., Chai, B., et al. (2019). Urban expansion and form changes across African cities with a global outlook: Spatiotemporal analysis of urban land densities. *Journal of Cleaner Production, 224*, 802–810. https://doi.org/10.1016/j.jclepro.2019.03.276
Zhang, X., Bao, H., & Skitmore, M. (2015). The land hoarding and land inspector dilemma in China: An evolutionary game theoretic perspective. *Habitat International, 46*, 187–195. https://doi.org/10.1016/j.habitatint.2014.12.002
Zhang, L., Zhang, L., Xu, Y., Zhou, P., & Yeh, C.-H. (2020). Evaluating urban land use efficiency with interacting criteria: An empirical study of cities in Jiangsu China. *Land Use Policy, 90*, 104292. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0264837719303886.
Zhao, X., Zhang, L., Huang, X., Zhao, Y., & Zhang, Y. (2018). Evolution of the spatiotemporal pattern of urban industrial land use efficiency in China. *Sustainability, 10*(7), 2174. Retrieved from http://www.mdpi.com/2071-1050/10/7/2174.
Zhu, X., Li, Y., Zhang, P., Wei, Y., Zheng, X., & Xie, L. (2019). Temporal–spatial characteristics of urban land use efficiency of China's 35mega cities based on DEA: Decomposing technology and scale efficiency. *Land Use Policy, 88*, 104083.
Zitti, M., Ferrara, C., Perini, L., Carlucci, M., Salvati, L., Zitti, M., et al. (2015). Long-term urban growth and land use efficiency in southern europe: Implications for sustainable land management. *Sustainability, 7*(3), 3359–3385.