

Greying in Gulu City: The Impacts to Climate Change and the Potential for Adaptation Using Green Infrastructure

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Abstract

This study investigates the climate change effects attributed to the dissipation of city greens and examines the prospects of using green infrastructure as an urban planning strategy for climate change adaptation. The study employed a multi-method approach involving empirical studies, desk studies, and remote sensing approaches including the *calculation of NDVI* generated in QGIS using a raster calculator. The study revealed a high estimated NDVI value of 0.96 in the wet season, while the lowest was -0.23 in the dry season. Built-up areas exhibited low NDVI values, while the green vegetated annexed areas exhibited high NDVI values. The proportion of tree cover in the suburbs was higher compared to that of the CBD, where trees and greenery are believed to have been cut down to pave the way for settlements, and the implementation of road infrastructure projects, thus the predominance of concrete. The result is associated with consequences such as increased temperatures for prolonged periods.

Keywords

Urban Green, Greying, Climate Change, Adaptation, Green Infrastructure

1. Introduction

Although green spaces and tree cover in urban areas have been known to offer rich benefits in adapting cities to climate change, through air purification, urban temperature regulation and runoff mitigation, the world cities are increasingly experiencing green space and tree cover depletion and replacement by impervious surfaces, partly caused by a myriad of factors including urban infrastructure provision, housing provision and urban expansion. This trend poses potential socio-environmental and climate change threats. Given urban greying due to the

depletion of tree cover, [Cuthbert et al. \(2021\)](#) in the Conversation report of 2021 reveal that “...temperatures in cities are often several degrees higher than rural areas, due to the ‘urban heat island’ effect, where the predominance of concrete and steel absorb and retain heat, and there is a lack of cooling by water evaporating from plants. These same heat-intensifying features are also often responsible for flash flooding in cities, as sealed surfaces cannot act like a sponge to soak up and store rain, unlike the soil they have replaced”.

While tree canopies continue to be damaged, their existence in any landscape is one of the simplest green infrastructure techniques to reduce stormwater runoff by intercepting rainfall, as well as by improving stormwater infiltration in soils. The presence of trees in urban areas has also been linked to improved human health through providing shade which shields people from the direct harmful ultraviolet rays from the sun.

In Gulu City, the dwindling of urban green, especially within the former municipal boundaries and in the central business district (CBD), has had associated consequences of flooding and increased temperatures. This is confirmed by the Third National Development Plan (NDPIII) which highlights that the districts such as Gulu, Kitgum, Kotido and Kasese registered a modest decrease in annual rainfall, implying higher temperatures, and prolonged dry spells. The erratic and poorly distributed rainfall amplifies the level of vulnerability ([NDP III, 2020: p. 97](#)), and therefore, the City authorities require the use of innovative solutions and the rethinking of urban management and planning ([Sturiale & Scuderi, 2018](#)). An assessment of the impact of dissipating urban green is very important. Therefore, this study investigates the proportion of green spaces, tree cover in Gulu city, and the climate change effects attributed to the loss of city greens. By extension, the study proposes the use of green infrastructure as an urban planning strategy for climate change adaptation.

2. Research Methodology

The study employed a multi-method approach involving the case study methodology in the selection of cases and units of analysis. The target population was the physical planning committee which comprised the heads of departments at the city level, all of whom were selected purposively and interviewed. The data/information relating to climate change adaption and green infrastructure was obtained through documents review; while spatial data on the existing greens in the city was obtained using hand-held Geographical Positioning Systems (GPS) equipment. Since this study involved an analysis of change detection of green versus greying, remote sensing approaches were employed:

Satellite imagery acquisition: The sentinel and Landsat satellite data (geocoded with UTM projection, spheroid, and datum WGS 1984, Zone 36 North) of the 10 m and 20 m spatial resolution were acquired from the open source site of the sentinel hub browser (<https://apps.sentinel-hub.com/eo-browser>). During the downloading process, an area of interest (AOI) was created comprising the former Gulu

municipal boundaries. Specifications were made about the cloud cover (less than 10%), period (2015-2022) and other data set requirements. Specific Image bands of sentinel 2 (B4, B8) and Landsat 8 (B4, B5) relevant for detecting vegetation index were downloaded. The acquired images were sorted and organized according to the selected years (2015, 2018, and 2022), and seasons (dry and wet).

Image pre-processing: Sequences of processes were carried out on the images before final analyses to improve visualization and reduce noise. These processes included; geo-referencing, haze reduction, noise reduction, and spectral corrections were done to choose the best band combinations for visualization of the images.

Calculating Normalized Difference Vegetation Index (NDVI): NDVI stands for Normalised Difference Vegetation Index which shows the greenness of vegetation, an index extracted from photosynthetic activity of vegetation (Nafarin & Novitasari, 2023). Normalized Vegetation Index (NDVI): is a remotely sensed index that is used to estimate the vegetation cover and its growth health. The proposed change detection is meant to provide a printable land cover and vegetation change estimate (Hartoyo et al., 2021). To compute it, the reflectance in the green and near-infrared bands of the electromagnetic spectrum of vegetation is employed. Therefore, the higher the density and health of the vegetation, the greater the numerical value of NDVI (Carbajal-Morán et al., 2023). A wide range of industries such as the forestry sector, agricultural production and ecological surveys have greatly applied NDVI. For them, such vegetation landscapes touch profoundly on the ecological environment and climate change in arid regions (Aini Rahmi et al., 2024). Therefore, it is clear that NDVI can be used efficiently in the fields while monitoring vegetation conditions (Yengoh et al., 2016). From the study, it is clear that NDVI can effectively detect the changes in biomass, land cover, growth and other parameters of vegetation (Aini Rahmi et al., 2024). Among various land indices, the vegetation index is one of the most common and effective in rapidly detecting vegetated regions with the help of multispectral remote sensing data. NDVI shows more sensitivity for crown density changes as compared to other vegetation indices of Abdusamea (2024).

Normalized Difference Vegetation Index (NDVI) uses the near-infrared (NIR) and red channels in its formula. Healthy vegetation (chlorophyll) reflects more NIR and green light compared to other wavelengths. Satellite sensors like Landsat and Sentinel-2 both have the necessary bands with NIR and red. The result of the above formula generated values between -1 and $+1$ as illustrated on the maps. In this study, large positive NDVI values show dense vegetation whereas negative and fewer NDVI values reveal the built-up areas or non-green.

NDVI is a fundamental tool in Vegetation Indices due to its ability to provide a precise measure of vegetation vigor and productivity hence a vital tool for evaluation of any environmental and ecological unit (Yengoh et al., 2016). Some key applications of NDVI include: Evaluating vegetation density and vigour and measuring primary biomass, drought perception, crop management, and evaluating the land cover and use change (Aini Rahmi et al., 2024; Aryal et al., 2022; Carbajal-

Morán et al., 2023; Essaadia et al., 2022; Hartoyo et al., 2021).

Generally, NDVI makes it possible to monitor the changes that occur in the terrestrial ecosystem due to population pressure and human interaction primarily through the calculation of NDVI which is detailed by Huang et al. (2021). NDVI is used considerably to quantify the changes in Land cover by human habitation, construction and other related activities as well as to quantify spatial and temporal variation in the area of vegetation cover of the region.

In this study, NDVI was generated in QGIS using a raster calculator with the following expression: $NDVI = (NIR\ B8 - RED\ B4) / (NIR\ B8 + RED\ B4)$, where NIR is near-infrared light and Red is visible red light.

3. Results

3.1. The Context of Gulu City

As per the 2020/2021-2024/2025 five-year development plan, Gulu town originated due to the colonial era’s influence, the East African railway line, and the presence of missionaries. After being established as a township in 1906, Gulu took on the responsibility of promoting trade, inter-settler’s communication, and the transshipment of northern Ugandan agricultural products. The town’s major grid-iron-plan was completed in 1915, and by that time, it had been designated as the colonial administrative centre for the northern area known as the Acholi District. Under the Urban Authority Act of 1964, which has since been repealed, Gulu became a Town Council in 1974 and then a Municipality in 1977 (Gulu City Council, 2020).

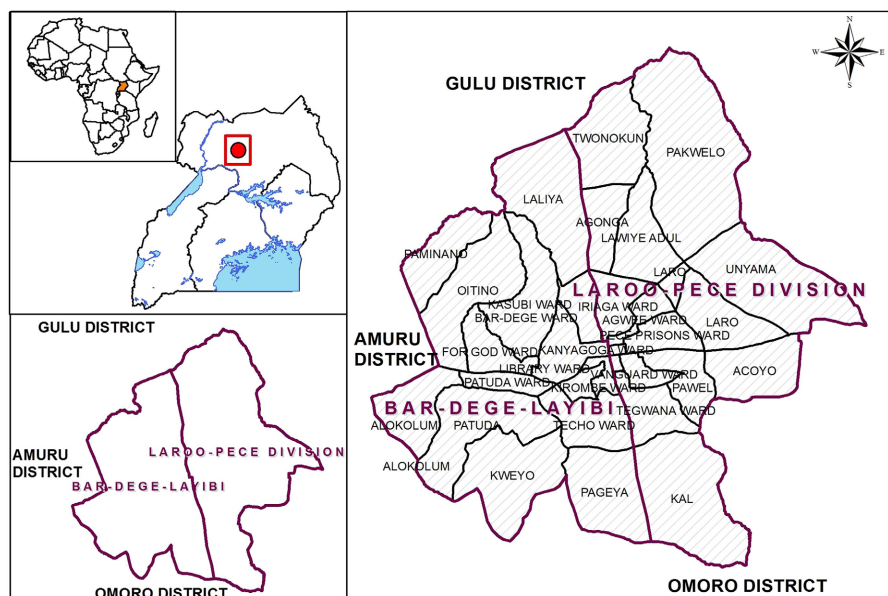


Figure 1. Location and context of gulu city.

It was among the very first Municipality in this Country. Gulu City was created through an Act of Parliament and became operational on 1st July 2020. Gulu City

lies approximately 332 km North of Uganda's Kampala City. It stands at 32° 17' longitude East and Latitude 2-47 North of Equator. Administratively, the City has two Divisions (as shown in **Figure 1**): Laroo-Pece Division and Bar-Dege-Layibi Division. The area coverage of Gulu City is approximately 225.65 sq-Km with a population of 409,941 as of 2020. However, initially, the municipality covered 54.6 sq-km, Gulu City is urbanizing rapidly; it is also emerging as the economic hub for Northern Uganda and is now poised to be the regional centre for economic growth and socio-economic transformation in the sub-region. These prospects make Gulu City an attractive destination for investment, innovation and thereby job creation (**Gulu City Council, 2020**).

3.2. Drivers for Urban Greying in Gulu City

The urbanization of Gulu City is partly attributed to the rapidly growing population of about 198,685 people as of 2022. The increase in population is largely driven by high fertility rates and rural-urban migrations (**Cities Alliance, 2018**). Secondly, the civil wars and the wars in the neighbouring countries *inter alia* South Sudan, Congo, and Somalia created an immense humanitarian crisis that internally displaced thousands of refugees, most of whom were hosted in Gulu town (**Kwiringira et al., 2021**). The influx of population into the city for security and safety created an exceptionally high pressure on land, thus urban densification and sprawling in most of the urban greenery and the natural ecosystems, turning them hard, impervious and grey. "The urban extent of Gulu Municipality between 2017 and 2020 alone was recorded as an increase from 12.289 km² to 16.606 km², a spatial growth of approximately 4 km²; mostly along the major roads..." (**Digital Earth Africa, 2020**).

Apart from the population factor, the depletion of green in Gulu city is also attributed to the clearing of tree cover and greenery in the implementation of the city infrastructure projects such as the road projects by Uganda Support for Municipal Infrastructure Development (USMID); the Japan International Cooperation Agency (JICA) drainage projects, the Gulu-Kitgum road project under Uganda National Roads Authority (UNRA) and the Zhong Mein Chinese contractors. The rate at which tree cover and greenery are getting depleted in the CBD of Gulu City is worrying. Interviews with the City's Physical Planning and Environment Officials intimated that developers have no respect for green and ecological areas around the city. Some of the developers were quoted saying, "Trees are not as important as houses or roads." As such most trees in the City center have been cut down, and Pece stream and Oitino swamp are facing severe encroachment.

Although attempts to replant new species were made (as shown in **Figure 2**) through a procured contractor, this did not yield positive results because of drought and the timing of the planting activity. Trees also faced destruction by street kids. The tree species planted including spear tree, palm and grevillea different from those that were felled; thus, communities were less satisfied with the

intervention, consequently the community policing responsibility was abandoned.

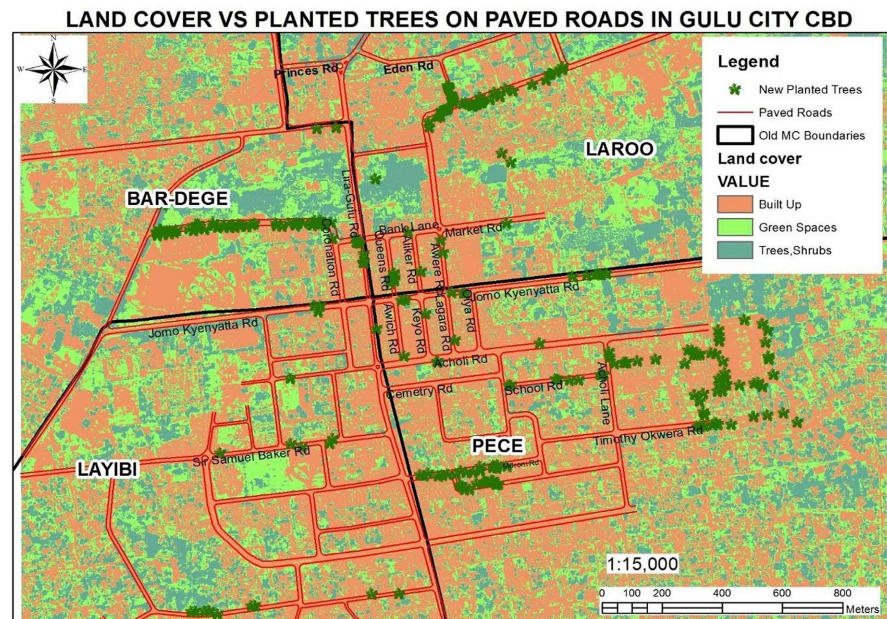


Figure 2. Showing replanted trees after road and drainage construction.

3.3. Establishing the Proportion of Urban Greying

The Normalized Difference Vegetation Index (NDVI) maps of Gulu city were reclassified into five classes namely: very low (red), low (orange), moderate (yellow), high (green), and very high (apple green) green quality.

The study revealed a high estimated NDVI value of 0.96 in the wet season, while, the lowest was -0.23 in the dry season. Built-up areas exhibited low NDVI values, while the green vegetated annexed areas exhibited high NDVI values. The class of high green quality was the dominant NDVI class in the outskirts of the Central Business District (CBD) whereas the very low green quality class was mostly dominated by built-up areas, and hence had negative NDVI values. Overall, the NDVI values showed much difference between the dry and wet seasons as illustrated in **Figure 3**, although the NDVI values in the CBD remain very low due to the density of built-up activities especially the paving of roads and the nature of building materials that absorb a lot of heat. The high green vegetation index in the outer areas of the CBD is an indication that the annexed areas of the new city have more green areas, significantly moderating the climatic condition of the suburb, and subsequently, improving the dwellers' health status better than those in the CBD.

The proportion of tree cover in the annexed areas was higher compared to that of the CBD, which was cut down during the road tarmacking projects. The trees in the suburbs are bigger and more mature compared to those that are newly planted. Those planted on the newly paved roads are also poorly managed.

NDVI 2015-2022 DRY AND WET SEASON

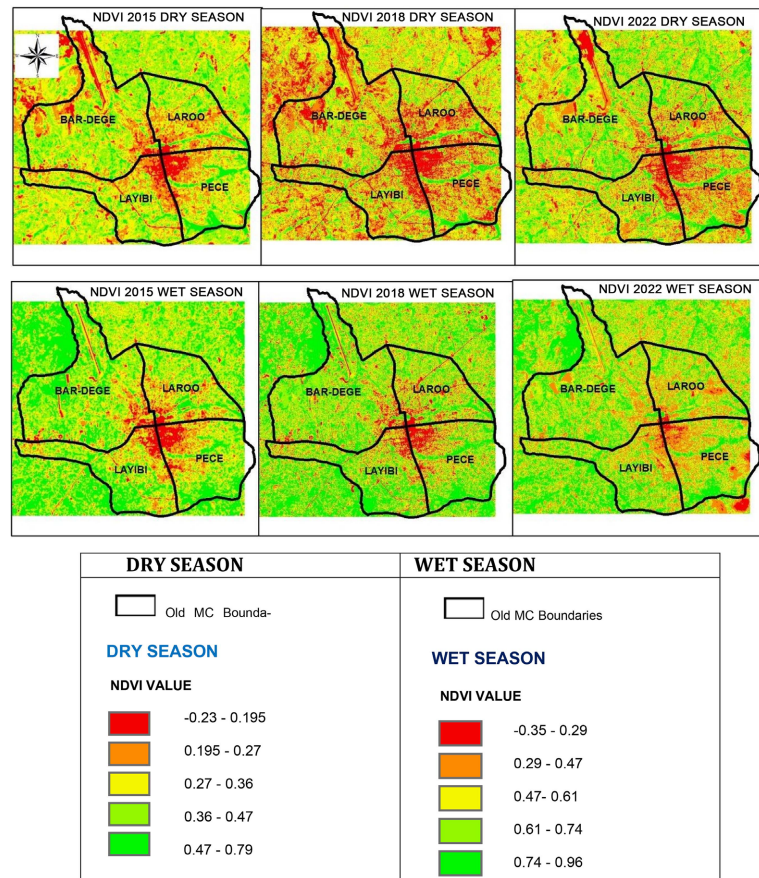


Figure 3. NDVI Values for Dry and Wet Seasons for 2015, 2018 and 2022.

3.4. Spatial Temporal NDVI Variability in Gulu City CBD

It can be noted that greenness increases with the increase of the positive NDVI values. But this varies according to different climatic conditions of both the wet and dry seasons. Generally, the wet season has more NDVI values compared to the dry season. However, it can be observed that both in the dry and wet seasons, the vegetation cover in the CBD remains very low because of the dense construction and little local vegetation.

The maps present the spatio-temporal changes in Vegetation cover of Gulu City CBD from 2015-2018 to 2022. Green vegetation decreased in a very high proportion while the built-up areas especially settlement and barren land increased at a very high rate between 2015 and 2018 due to rapid land conversion caused by the massive pressure for settlements, urban sprawl, migrations, and infrastructure development as a result of change in status from a municipality to a city.

Also, NDVI maps directly relate to the climatic data both in the dry and wet seasons. The Low NDVI values reveal the increase in urban heat island and thus an increase in the land surface temperatures in the CBD of Gulu city. The high NDVI is related to the healthy and green plants that reduce the intensity of land surface temperature as compared to the low NDVI values. The excessive heat in

the CBD underpins that the land use, occupation, and the specialization of geo-ecological and geo-urban elements collaborate in the heat storage of the different types of building materials, roofs, and surfaces that constitute the urban environment. It is reflected in the distribution and concentration of heat under the land surface.

As illustrated in **Table 1**, the NDVI value was found higher in 2015 and in 2018, the NDVI value decreased due to tree felling and land conversion. The NDVI value in 2022 slightly improved after the growth of the planted trees along the tarmacked roads. However, in general the green cover in the city remained ecologically poor. The very low NDVI values characterize the CBD environment as impermeable surfaces, with building materials that have high heat concentration, and little vegetation, among other factors that prevent the exchange of energy between the atmosphere and surface.

Table 1. Spatial-Temporal variation of NDVI values.

2015 DRY	2015 WET	2018 DRY	2018 WET	2022 DRY	2022 WET
-0.39	0.03	-0.23	-0.35	-0.30	-0.32
0.22	0.34	0.19	0.29	0.22	0.26
0.31	0.47	0.27	0.47	0.33	0.43
0.38	0.56	0.36	0.61	0.42	0.56
0.46	0.63	0.47	0.74	0.53	0.69
0.74	0.79	0.79	0.96	0.81	0.89

3.5. Climate Change Impacts in Gulu City

The results of the study indicate that Gulu City like other parts of Northern Uganda experiences unimodal rainfall pattern, that is April, May, June, July, August, and September. The months of October and November are vulnerable to drought and associated impacts as illustrated in **Figure 4**.

Meteorological data of rainfall for years from 2015 to July 2022 shows that over the years, the rainfall totals in Gulu were below 400 mm except for 2019 which had a shoot-up of about 483 mm in June. These rains were below the normal threshold of 500 mm signifying climate change. This could be attributed to both natural factors and human activities such as deforestation, destruction of green spaces, and replacing them with more grey spaces. Furthermore, according to the El Nino and La Nina calendar, 2021 and 2022 are moderate La Nina years and 2015 together with 2016 were very strong El Nino years. This could also be one of the factors that affected the rainfall totals. The decrease in rainfall resulted in significantly drier conditions for much of the year. This, combined with significant temperature increases leads to urban heat islands.

Overall, the City experiences changes in the temperatures and greater weather extremes. The temperatures are categorized into maximum and minimum temperatures. The meteorological temperature data obtained from Uganda National

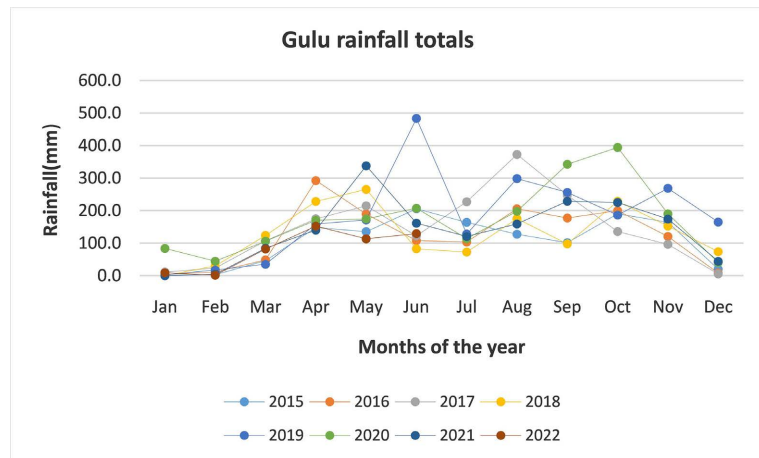


Figure 4. Gulu city rainfall totals.

Meteorological Authority (Figure 5) illustrates that the minimum temperatures from 2015 to 2022 were almost constant with exemptions of a rise in November and December in 2019 and 2017. This could be attributed to increased destruction of the environment as people cut down trees for settlements and urban uses as well as for charcoal burning and firewood as a source of livelihood. In the CBD of Gulu city, most trees were cut down to pave the way for new infrastructural investments and upgrading of existing infrastructure.

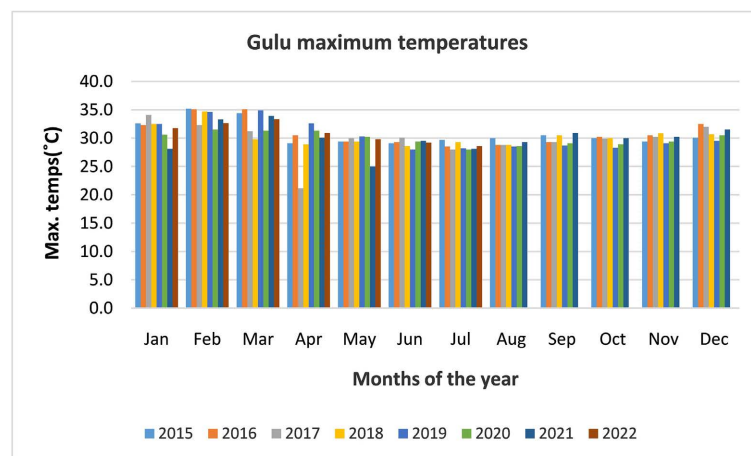


Figure 5. Gulu city minimum temperatures.

The ensuing graph (Figure 6) illustrates that there was a sharp fall in maximum temperatures at the onset of the rainy season that is to say March to June, which later regulated from June to December. This scenario can be attributed to increased moisture in the atmosphere and vice versa. The temperatures are average within 30°C implying too much heat which affects both human and animal health and death of green cover.

Relative humidity (RH) is closely tied to temperature. As air temperature increases, air can hold more water molecules, and its relative humidity decreases.

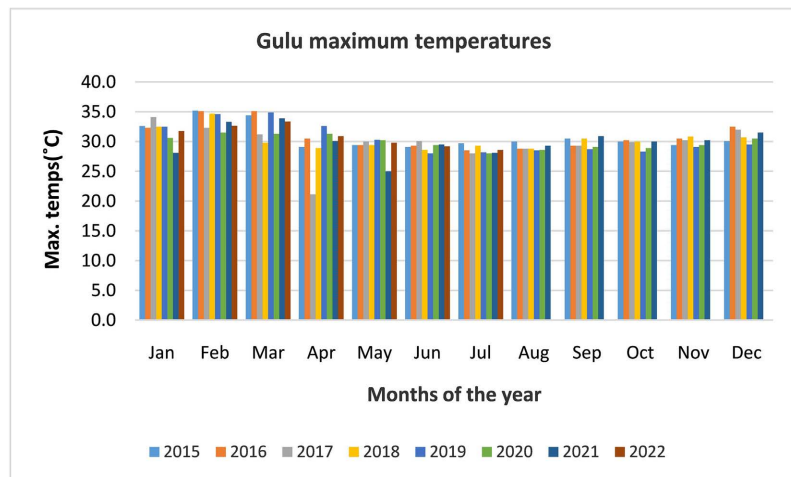


Figure 6. Gulu city maximum temperatures.

When temperatures drop, relative humidity increases. Figure 7 illustrates that relative humidity was low in November, December, January, February and March well and the rest of the months had high relative humidity. Higher RH, means increased vegetation as it supports biological growth and the reverse is true.

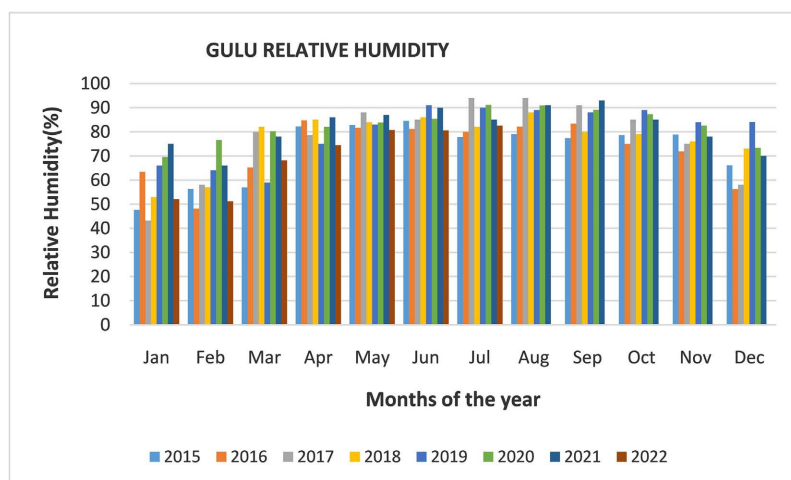


Figure 7. Gulu city relative humidity.

The findings of this study are in line with the Uganda National Urban Climate Change Profile Final Report published by the Ministry of Lands Housing and Urban Development (MLHUD) (2018), which reveals that the northern region of Uganda and in particular the urban centres of Arua, Gulu, Lira and Moroto are projected to decrease in annual rainfall of between 1 and 10% by the year 2050, while Amudat and Paidha will have slightly increased rainfall in the same period. The report also notes that the Urban Centres in the north will be slightly warmer than other centres in other regions by 0.1 °C and 0.2 °C. The implications of changing rainfall and temperature trends/patterns worsened by lower humidity imply that the City will experience longer drought and water shortages.

3.6. Why Adaptation and Green Infrastructure?

Since attempts at mitigation have been futile, cities today should play a larger role in building resilience and adaptation (World Bank, 2011; Sturiale & Scuderi, 2019). According to Sturiale and Scuderi (2018), "...several studies show the existence of important links between urban greening and impacts on climatic conditions: Parks and trees offer shaded areas and help to cool the air, they are places to find relief during heat waves, they offer plant cover, and they protect from solar radiation; the integration of vegetation in the facades and on the roofs of buildings helps to balance the interior temperatures as well as protect the structures." The demands for the promotion of greening for climate change adaptation are expressed in Uganda's National Urban Policy, 2017, Objective 4, which seeks to promote urban environment conservation and protection. Under Policy Statement 10. The Government shall ensure the provision and protection of public open spaces in urban areas through the strategy of prioritizing the provision of safe, inclusive, accessible, green, and quality public spaces, friendly for urban dwellers; and by gazetting all public open spaces and recreational areas and monitor the implementation of their development (MoLHUD, 2017).

Green Infrastructures and their integration into urban planning would potentially improve the microclimate and other impacts of climate change such as flooding and the urban heat island effect. Such natural interventions are increasingly being recognized as a desirable "win-win" approach to combating climate change, as they also help to deliver multiple other social, economic, and environmental benefits (Sturiale & Scuderi, 2019). Similarly, "...the maintenance of urban green spaces is one of the approaches suggested by SDG 11 (Sustainable Cities and Communities) of the UN Agenda, to make cities inclusive, safe, resilient and sustainable" (UN, 2015; Sturiale & Scuderi, 2019), partly through creating green spaces and improving urban planning and management in inclusive and participatory manner. In this regard, many efforts can potentially be put in place to build urban resilience and develop socio-ecological adaptive capacity. One such effort is urban greening and the use of Green Infrastructure (GI) in spatial planning. The term green infrastructure is relatively new; however, the concepts that underpin it can be traced back to the beginnings of environmentalism, nature conservation, landscape architecture and planning (Pankhurst, 2010 in Sussams et al., 2015). Sussams et al. (2015) further note that Climate change considerations are increasingly significant in the application of environmental management tools. Gradually, the focus on climate change adaptation within climate change policy has been growing due to the increasingly grave predictions from climate change science.

Green Infrastructure (GI), according to the European Union definition, "... are networks of natural and semi-natural areas planned at the strategic level with other environmental elements, designed and managed in such a way as to provide a wide spectrum of ecosystem services, while also enhancing biodiversity (European Commission, 2013)". In the EU, the term GIs was first introduced in the

2009 Commission White Paper, “Adapting to Climate Change” (EU, 2009). In all the normative Acts of the EU, the term “Green Infrastructure” is used in connection with landscape resources, with particular emphasis on ecological connectivity. Sturiale and Scuderi (2019), intimate that GI and their integration into urban planning appears to be one of the most appropriate and effective ways to improve the microclimate. GIs are in various forms including, green roofs, green walls, urban forests, bioswales, rain gardens, urban agriculture (urban gardens; community gardening; collective green; peri-urban agriculture, agricultural parks), river parks, local products markets, areas of constructed wetlands, alternative energy farms, and nature conservation areas, among the most common (Sturiale & Scuderi, 2019).

According to Foster et al. (2011), “the application of green infrastructure approaches ranges in scale from individual buildings, lots and neighborhoods to entire cities and metro regions and the benefits range in scale”. Accordingly, Green infrastructure can be implemented via large centralized public “macro” projects or smaller decentralized “micro” applications on private property. The climate adaptation benefits of green infrastructure are generally related to their “ability to moderate the impacts of extreme precipitation or temperature; better management of storm-water-runoff, lowered incidents of combined storm and sewer overflows (CSOs), water capture and conservation, flood prevention, storm-surge protection, and reduced ambient temperatures and urban heat island (UHI) effects” (Foster et al., 2011).

4. Appropriate Techniques for Gulu Central Business District (CBD)

The new Gulu City Physical Development Plan has a goal to address environmental issues and climate change, and to transform the city into a Green City. The interventions are focused on zoning green public parks and green spaces; green corridors and buffers for wetlands. These interventions are largely out of the CBD areas. The CBD requires a combination of approaches. The challenge, however, is that there seems to be a narrow understanding by the local urban managers of the Green City concept; which particularly is seen in the light of city beautification and recreation.

In this regard, Adaptation planning shall be key in ensuring climate-proofing. In congruence with Foster et al. (2011) and Sturiale and Scuderi, (2019) “Green space retrofitting should be considered to increase the quality and attractiveness of the public space and to reduce economic losses during cloud bursts and heavy rains”. The approach could include the redesign and improvement of green infrastructures such as urban parks, green city corridors, tree planting, etc. as well as other types of interventions that use Nature-based Solutions to provide some form of adaptation to climate risks”, in the following ways:

- 1) The nature of the CBD surfaces in Gulu City calls for the addition of trees to a landscape as one of the simplest green infrastructure techniques. Tree canopy

can reduce storm-water runoff by intercepting rainfall, as well as by improving storm-water infiltration in soils and improving air quality.

2) Secondly, the hard landscape pallet used in all the city streets in Gulu is impervious; permeable pavements may be constructed from pervious concrete, porous asphalt, permeable interlocking pavers, and grid pavers. This is also a storm-water drainage system that allows rainwater and runoff to move through the pavement's surface eventually seeping into underlying soils.

3) Integrating green infrastructure elements into the street and/or alley design to store, infiltrate and infiltrate stormwater. Permeable pavements, bioswales, planter boxes, and trees are among the many green infrastructure features that may be woven into street or alley designs.

4) Similar to rain gardens, planters or tree boxes utilize soil, gravel, and plants to infiltrate and filter storm-water runoff from impervious surfaces. Planter boxes are typically smaller than rain gardens and are used in urban communities such as long sidewalks, roadways, and parking lots. They are typically rectangular with concrete sides and an inlet that allows stormwater to enter the planter box.

5. Conclusions

5.1. The Proportion of Green Spaces, and Tree Cover in Gulu City

This study has attempted to examine the dwindling urban green especially within the former municipal boundaries and in the central business district of Gulu City. Normalized Difference Vegetation Index (NDVI) of Gulu city reveals a high value of 0.96 in the wet season, while the lowest was -0.23 in the dry season. Built-up areas exhibited low NDVI values, while the green vegetated annexed areas exhibited high NDVI values. This reflects the distribution and concentration of heat under the land surface. The NDVI value in 2022 slightly improved after the growth of the planted trees along the tarmacked roads by the Gulu city council and many non-government sectors, but still, the green cover in the city is ecologically poor.

Urban green and tree cover in the CBD of Gulu City is very limited as is the case with most other urban Centres within Uganda attributed to increased urbanization and various factors that hinder their management and conservation. Thus, it is critical to address the challenges and to prioritize the development of urban trees and green spaces to enable Gulu City, to obtain the numerous social, environmental, and economic benefits of green infrastructure.

5.2. The Climate Change Effects Are Attributed to the Loss of City Greens

The very low NDVI values characterize the CBD environment as impermeable surfaces, with building materials that have high heat concentration, and little vegetation, among other factors that prevent the exchange of energy between the atmosphere and surface.

The modernity trajectory is already claiming the city greens that are fundamental

to mitigating the effects of climate change; it is already making the temperatures in the central business district of Gulu City higher; this can be observed after a heavy downpour and worst at night.

Housing developments in Gulu City, particularly the CBD, have led to the elimination of city greens and in the process reduced Gulu City's ability to sequester carbon, thus resulting in higher emissions from auto-mobility, among other sources.

There is more runoff and higher susceptibility to floods, especially during rainy seasons due to paved surfaces through the creation of roads or the eradication of vegetation. The ecosystem services that are cardinal to an urban environment such as air purification, noise dampening, and regulation of temperature in the CBD of Gulu City are also declining due to vegetation loss or non-availability of green space. All these make the CBD of Gulu City unconformable, thus having an impact on the health of persons working or living in it.

5.3. The Use of Green Infrastructure as an Urban Planning Strategy for Climate Change Adaptation

Improving the urban environment condition of Gulu City through the protection and rejuvenation of the greenery and green infrastructure will be of great significance in reducing the gap in tree cover. There is a need for the City managers and city planners to consider improving the urban environment conditions to increase the city's greenness index. The presence of urban trees increases humidity values, playing a significant role in channeling winds, which are fundamental conditions for dissipating heat from human action. Besides, it attenuates the high surface and air temperatures.

6. Recommendations

This paper highlights the need for community involvement in the foreseeable future management and the climate change adaptation benefits to be derived from the green infrastructure. Residents' involvement in the planning processes of green infrastructure can assist with the development of successful projects.

The view on the preservation and expansion of Green Infrastructure is fundamental when it comes to the enhancement of climate change resilience in cities. This means that there is a need for serious dedication by the local government, city planners and the communities if they are to overcome the challenges that have limited the advancement of city greenery and green infrastructure.

The use of green infrastructure like parks, gardens, urban forests and urban trees in cities is useful in climate adaptation because it aids in decreasing the effects of urban heat islands, managing stormwater, and improving the livability of cities.

The Possible Areas to Improve the Research Include

Conducting a comprehensive survey and mapping of the existing green

infrastructure, including both formal and informal green areas.

An investigation on how residents of Gulu City, including different socio-economic and demographic groups, perceive the value and functionality of green infrastructure

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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