

Impacts of urban forestry on reducing heat islands in the communes of Golfe 5 and 7, Lomé (Togo)

Impacts de la foresterie urbaine sur la réduction des îlots de chaleur dans les communes de Golfe 5 et 7, Lomé (Togo)

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Abstract

This study was conducted in the communes of Golfe 5 and 7, aims to contribute to a better understanding of the role of urban forestry in reducing heat islands in urban areas. It involved: (i) mapping the spatial distributions of land surface temperature variations and the distributions of vegetation cover and building areas in the communes of Golfe 5 and 7, and (ii) identify local people's perceptions of heat islands. To achieve these objectives, a Landsat satellite image and a land surface temperature image coupled with field data were used. The analysis of land use revealed a predominance of building areas/bare ground (46.60% in Golfe 7 and 67.74% in Golfe 5) and croplands/fallow land (47% in Golfe 7 and 28.18% in Golfe 5) in the two communes, with an uneven spatial distribution of the heat island (HI). The variation of the heat island according to land-use units showed that the hottest areas (UHI:[0.1, 0.2]) were characterized by a dominance of building areas/bare ground and croplands/fallow land. The areas of dense forests/plantations, savannahs and water areas have relatively low and very low temperatures (UHI:[-0.1, 0]; ≤-0.1). The hottest areas was more represented in the Golfe 5 commune than Golfe 7. Surveys of 141 people in the communes of Golfe 5 and 7 showed that the majority perceived the heat to be more intense at midday than at night.

Keywords: heat island, land use, urban forestry, Lomé, Togo

Résumé

Cette étude, menée dans les communes de Golfe 5 et 7, vise à mieux comprendre le rôle

de la foresterie urbaine dans la réduction des îlots de chaleur urbains. Elle a consisté à : (i) cartographier la répartition spatiale des variations de température de surface et la distribution du couvert végétal et des surfaces bâties dans les communes de Golfe 5 et 7, et (ii) identifier la perception des îlots de chaleur par les populations locales. Pour atteindre ces objectifs, une image satellite Landsat et une image de température de surface, combinées à des données de terrain, ont été utilisées. L'analyse de l'occupation des sols a révélé une prédominance des zones bâties/sols nus (46,60 % à Golfe 7 et 67,74 % à Golfe 5) et des terres cultivées/jachères (47 % à Golfe 7 et 28,18 % à Golfe 5) dans les deux communes, avec une répartition spatiale inégale des îlots de chaleur. La variation de l'îlot de chaleur urbain selon l'occupation du sol a montré que les zones les plus chaudes (ICU : [0,1 ; 0,2]) étaient caractérisées par une prédominance de zones bâties/sols nus et de terres cultivées/jachères. Les zones de forêts denses/plantations, de savanes et de plans d'eau présentaient des températures relativement basses, voire très basses (ICU : [-0,1 ; 0] ; ≤-0,1). Les zones les plus chaudes étaient davantage représentées dans la commune de Golfe 5 que dans celle de Golfe 7. Des enquêtes menées auprès de 141 personnes dans les communes de Golfe 5 et 7 ont montré que la majorité d'entre elles percevaient la chaleur comme plus intense à midi que la nuit.

Mots clés : Îlot de chaleur urbain, aménagement du territoire, foresterie urbaine, Lomé, Togo

1. Introduction

Rapid urbanization and climate change are jointly contributing to the worsening of the urban heat island (UHI) phenomenon on a global scale (Jato-Espino 2019). Significant increases in ground-level temperatures lead to the formation of urban heat islands (UHIs) in areas with high population density and low vegetation cover (Filiatreault 2015). This phenomenon disrupts not only the environmental balance but also social dynamics by limiting outdoor activities and reducing the quality of life in urban areas (Balandi et al. 2025).

In Togo, particularly in Lomé, there has been a significant rise in average temperatures, reaching approximately 1.6 °C between 1961 and 2010 (Badameli and Dubreuil 2015). Reports indicate significant warming, largely attributed to rapid urbanization and sustained population growth. Lomé, which has a population of 2,188,276 according to the latest RGPH-5 data (2022), is facing increasingly frequent heat waves (Polorigni 2019). This critical situation requires special attention. In this context, urban forestry emerges as a promising area for research and action, offering solutions to mitigate high temperatures in urban environments.

This study focuses on the Golfe 5 and 7 districts of the city of Lomé. Through an in-depth analysis of temperature distribution, vegetation cover, and local perceptions, the study will provide scientific data to inform the development of strategies aimed at creating greener and more sustainable cities. With this in mind, there is an urgent need to better understand the role of urban forestry in reducing heat islands in urban areas. To this end, the study aims to: (i) map the spatial distribution of ground-level temperatures and land use in the Golfe 5 and Golfe 7 districts; and (ii) analyze residents' perceptions of heat islands in these areas.

2. Materials and Methods

2.1. Study area

The study took place in two communes of the Greater Lomé Autonomous District (DAGL), namely Golfe 5 and 7. The Golfe 5 commune is urbanized and has less vegetation (urban forest). On the other hand, the Golfe 7 commune is a peri-urban area and has a lot of vegetation. Those different characteristics motivate the choice of the two communes.

The DAGL is a territorial entity with legal personality and financial autonomy, made up of thirteen (13) communes by the law on the allocation and functioning of June 2019. With a surface area of 425.6 km², it is located between 6°07' and 6°31'N and between 1°12' and 1°44'E, in the Maritime region and in ecological zone V. It is bordered to the south by the Atlantic Ocean, to the west by the Aflao-Ghana border and the Avé prefecture, to the north by the Zio prefecture and to the east by the Lacs prefecture. The administrative division gives it the prefectures of Agoè-Nyivé and Golfe (Figure 1).

The DAGL population is increasing rapidly, rising from 390,000 in 1981 to 2,188,376 in 2022 (RGPH-5 2022). This urbanization is leading to a decline in vegetation cover, which fell from 85.98% to 40.78% between 1988 and 2022 (Deton et al. 2025), thus contributing to the accumulation of heat island effects in the urban environment.

Maximum temperatures in March and April (28°C) are recorded during the dry season, and minimum temperatures in August (25°C) are recorded during the rainy season. This thermal dynamic is exacerbated by uncontrolled urbanization, which poses additional challenges for the management of natural resources and the quality of life of city dwellers.

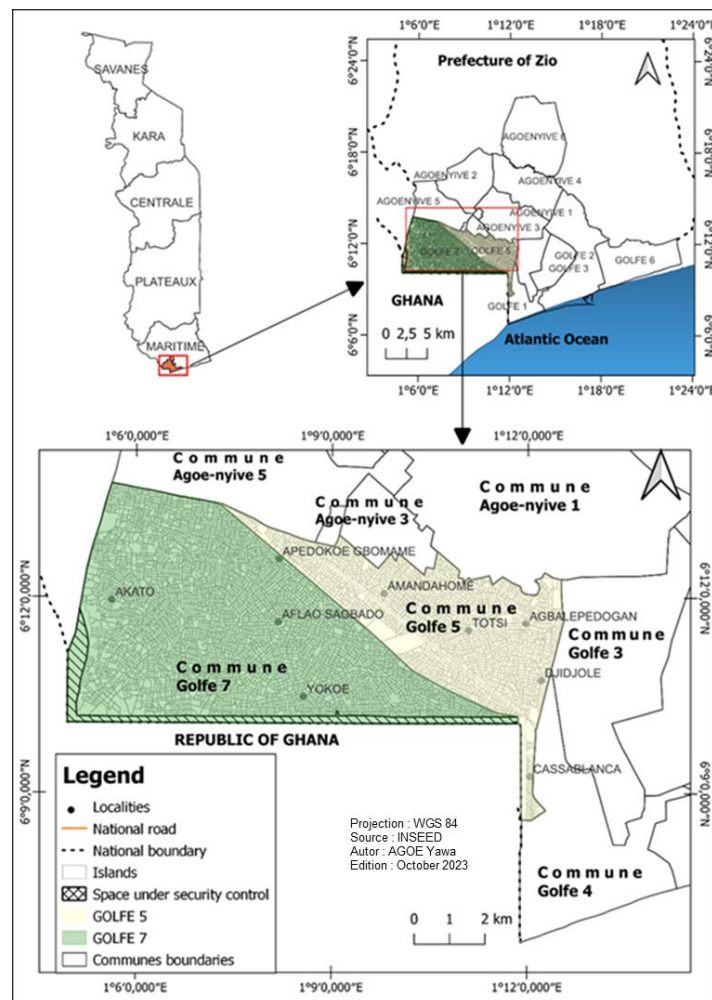


Figure 1. Geographical location of Commune Golfe 5 and 7 in the Maritime region of Togo

2.2. Data collection

2.2.1. Acquisition of temperature and vegetation images of the Golfe 5 and 7 communes

The land surface temperature (LST) image from 2023 with a temporal resolution of 1 year and a spatial resolution of 30 m was used for the urban heat island analyses. Landsat 8 OLI/TIRS image from 2023 with a resolution of 30 meters was used for land cover analysis. These images were downloaded from the Google Earth Engine platform. A total of 48 field points (Figure 2) were used to verify and validate the land cover classification.

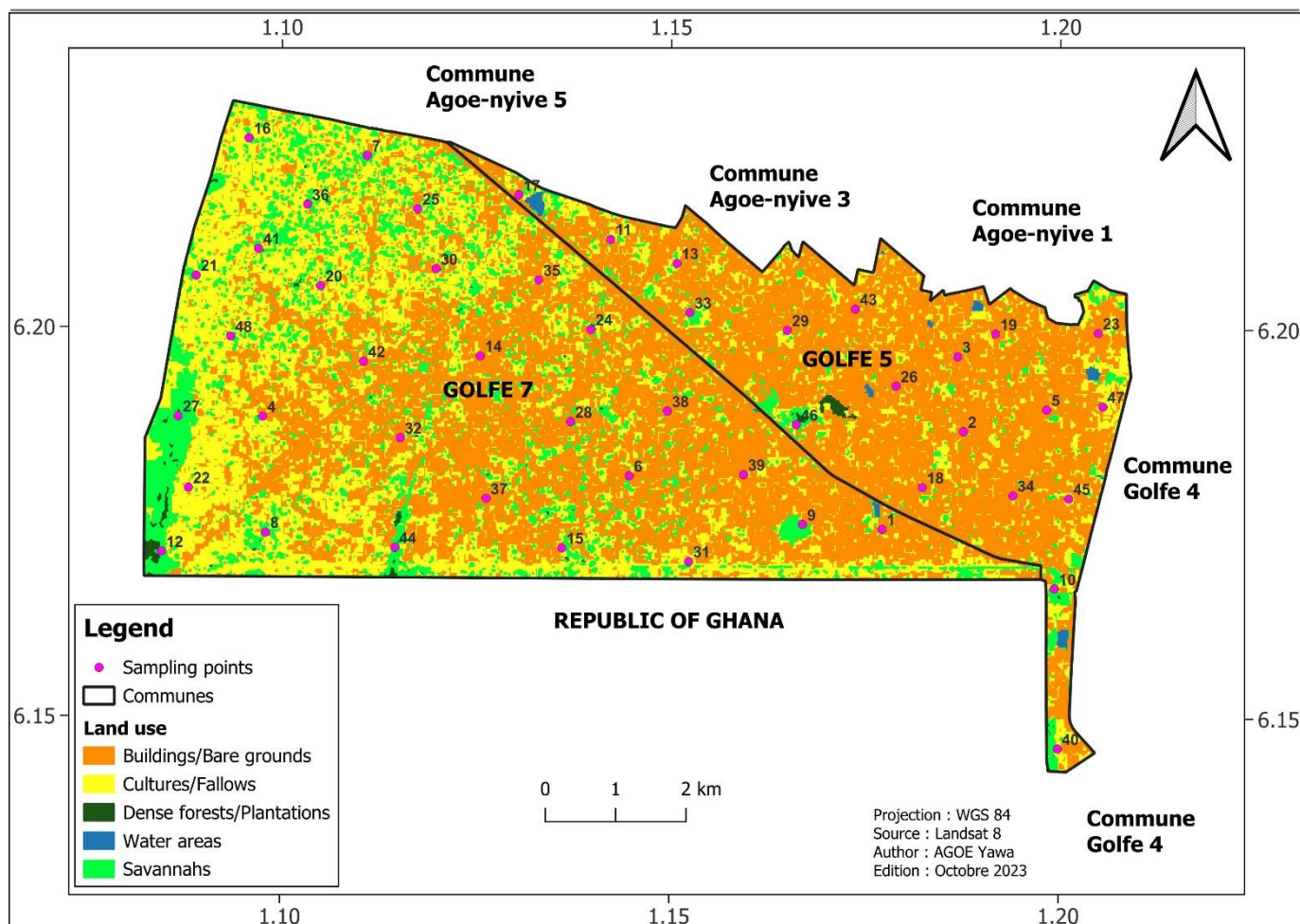


Figure 2. Sampling points

2.2.2. Survey

Based on random sampling, 141 people were identified in the two municipalities, regardless of age or sex (Atakpama 2010). Semi-directive surveys using individual interviews and focus groups (Atakpama 2010) were carried out on respondents from various ethnic groups: Ewé (55%), Kabyè (17%), Mina and Guin (11%), Tem (6%), Moba (5%), Akposso (3%), Nawda (2%) and Adja (1%) (Figure 3). The perceptions of men (63%) and women (37%) residents on heat islands, adaptation strategies and means of mitigation were collected using questionnaires implemented on the kobotoolbox platform (<https://ee-eu.kobotoolbox.org/x/jHaagh4e>). Open-ended and multiple-choice questions were used. The majority of respondents have a secondary education (63.69%), followed by university education (22.92%), and 1.27% are illiterate. Thirty-seven per cent of respondents are over 45 years of age. The 25-35 age group accounts for 27% of respondents, while 13% of respondents are aged between 15 and 25. The size of the study sample (n) was obtained by applying a sampling rate (t) of 1/250 Ardilly (1994), and the number of households N was identified by dividing the neighborhood population by the average household size in Lomé (RGPH-5 2022).

$$N = P/x \quad (1)$$

N : number of households (35937) ; P : Population of selected neighborhoods (179 686) ; x : Average household size in Lomé (5).

$$n = N/t \quad (2)$$

N : number of households, t : survey rate (1/250) ; so $n = 143.7$ or 144.

Choice of neighborhoods based on temperature variations on the Land Surface Temperature map for 2023 (Figure 3).

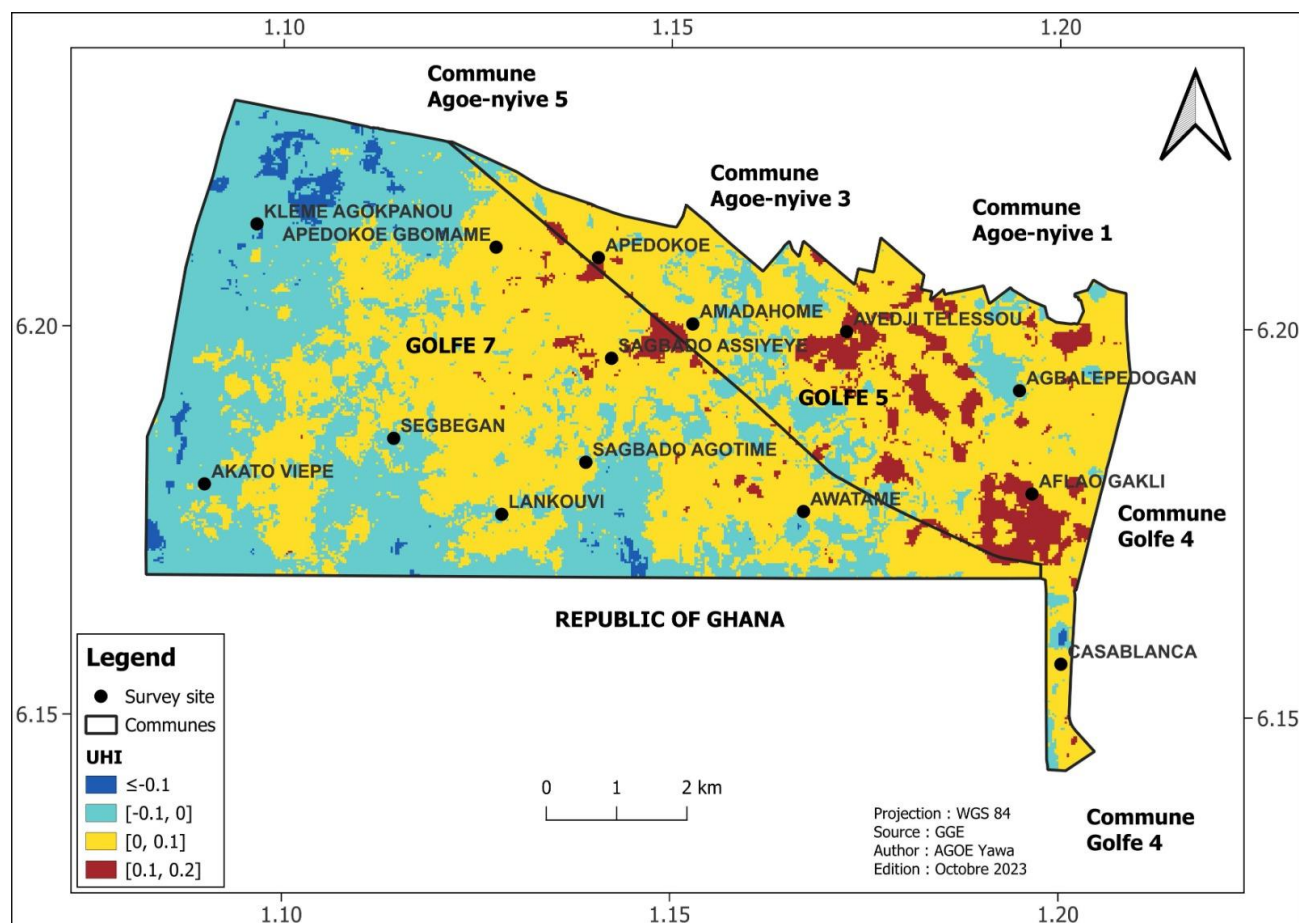


Figure 3. Distribution of daytime temperatures in the Golfe 5 and 7 commune

2.3. Data processing: Spatial distribution of temperature variations and land use and local people's perception of heat islands in Golfe communes 5 and 7

The analysis of land surface temperature (LST) data was conducted using a structured methodological approach that combined the processing capabilities of Google Earth Engine and QGIS software. First, the LST image for the year 2023 was downloaded from the Google Earth Engine platform. This image was then imported into QGIS to carry out the various stages of processing and spatial analysis.

To determine the reference temperature needed to calculate the urban heat island (UHI) effect, the peri-urban municipality (Golfe 7) was selected. After extracting this municipality, a regular 30 m × 30 m grid was superimposed on the LST to ensure homogeneous spatial sampling. The centroids of each grid cell were then generated, and a random sample of 200 points was selected. The surface temperature values corresponding to these points were extracted. The average of these values was used to determine the reference temperature (T_s). Next, the urban heat island intensity was calculated for each pixel of the LST image.

For each image, the following formula was used to determine the UHI:

$$UHI = (T_i - T_s) / T_s$$

T_i represents the surface temperature of a given pixel, and T_s represents the average reference temperature of the rural area.

The results were subjected to thematic classification in order to distinguish the different levels of urban heat island intensity.

This method have allowed the evaluation of the temperature fluctuations across the urban–peri-urban gradient. To facilitate the interpretation of UHI patterns, UHI values were classified into five intensity levels, as summarized in Table 1 (Balandi et al. 2025).

Table 1. UHI level

UHI	Level	Description
$HI \leq 0$	Very low	Extreme low-temperature zone, meaning that there is no difference in LST between urban and rural areas.
$0 < UHI \leq 0.1$	Low	Low-temperature zones mean minimal LST variation between urban and rural areas.
$0.1 < UHI \leq 0.2$	Medium	Medium-temperature region, meaning that the LST differs moderately between urban and rural areas.
$0.2 < UHI \leq 0.3$	High	High-temperature zone, meaning large urban/rural LST difference.
$0.3 < UHI$	Very high	An extremely high-temperature zone, meaning a huge urban/rural LST difference.

(Source : Balandi et al. (2025))

For the analysis of land use, the processing was carried out in four (4) phases, namely radiometric/atmospheric correction, extraction of the study area (Golfe 5 and 7 municipalities), classification and vectorization. Radiometric/atmospheric correction consisted of correcting the Landsat image using the 'Radiometric Correction' tool in the ENVI software. Extraction of the multispectral image of the study area consisted of cutting out the pre-processed images by superimposing the outlines of the two municipalities on them. Classification was based on knowledge of the field, field verification data and Google Earth images. This involved the visual identification of a number of natural or artificial elements or objects that could be point, linear or surface features on the image. The RGB-6-5-4 color composition was created using a combination of spectral bands based on the principle of assigning image bands to three (3) display planes based on three (3) primary colors: red, green and blue (Kombate et al. 2023). After the field mission, the supervised image classification was recommended using ENVI 4.7 software, with 48 ground truth points. The supervised classification method based on the maximum likelihood algorithm was used (Kombate et al. 2020). The first stage of this classification consisted of defining ROI (Regions of Interest) training zones, followed by a description of the different classes based on ground truth points and Google Earth images. Based on the training zones defined, the software generalized the processing over the entire surface area of the study zone. In order to improve the sharpness of the processed Landsat image, three (3) filtering operations were applied: 'Sieves classes' to eliminate isolated pixels, 'Clump classes' to homogenize the classes and 'Majority/minority' analysis to smooth the classes. The raster image was then vectored (Atakpama et al. 2023) and exported to QGIS 3.30 for layout. The attribute table of the classified image was exported to Microsoft Excel in order to calculate the areas of the different land-use units. Five (5) land use classes were defined, namely: croplands/fallow, buildings/bare grounds, savannahs, water area and dense forest/plantations.

To analyzed the UHI variation as a function of land use, the UHI and the land use images were intersected in QGIS 3.30 software. All analyses were performed in R statistical software, version 4.5.2 (Team 2022).

The information obtained in the field (Survey) was processed using Excel 2019. This processing provided figures that enabled us to highlight the public's perception of heat islands.

3. Results

3.1. Spatial distribution of temperature variations and land use in the Golfe 5 and 7 communes

• Classification accuracy

Assessment of the accuracy of the classification of the Landsat 8 image in 2023 shows an overall accuracy of 99.16%, with a kappa index of 0.75 (Table 1). The classification therefore appears sufficiently robust.

Table 1. Classification accuracy of Landsat images from 2023

Land use	Buildings/Bare grounds	Croplands /Fallows	Water area	Dense forests/Plantations	Savannahs
Buildings/Bare grounds	8726	357	7	3	1
Croplands/Fallows	1562	5376	7	3	169
Water area	5	6	850	289	272
Dense forests/Plantations	0	1	103	4047	538
Savannahs	32	291	81	899	1774
Total	10325	6031	1048	5241	2754
Overall accuracy: 99.16%, Kappa coefficient: 0.75					

(Source : AGOE, 2023)

• Spatial distribution of land use

The analysis of land use in 2023 reveals that buildings/bare grounds and the croplands/fallows are the most represented in the two communes Golfe 5 and 7 (Figure 4). In the Golfe 7 commune, the croplands/fallows (47 %) and the buildings/bare grounds (46.60%) are the dominant land-use units, followed by savannahs, water area and dense forests/plantations, respectively 6.18%, 0.13% and 0.08% (Table 2).

On the other hand, in the commune of Golfe 5, the surface area of buildings/bare grounds (67.74%) followed by croplands/fallows (28.18%) are the most dominant, while savannahs (3.14%), water area (0.73%) and dense forests/plantations (0.21%) are not very representative (Table 2).

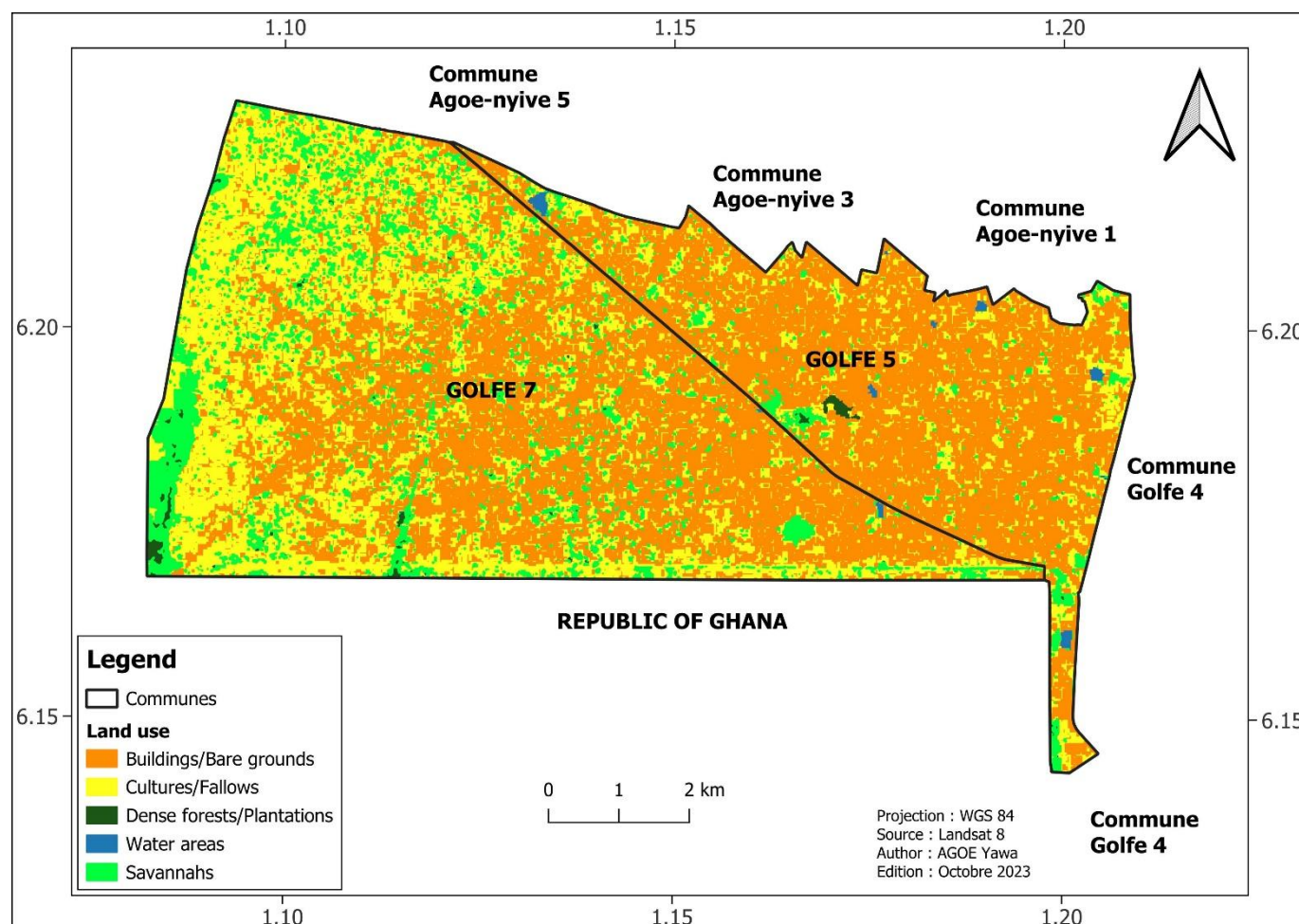


Figure 4. Land use of 2023 in the communes of Golfe 5 and 7 (Source: Landsat 8 image)

Table 2. Proportion of land use by municipality

Land use	Areas Golfe 5		Areas Golfe 7	
	Ha	%	Ha	%
Buildings/Bare grounds	1533.93	67.74	2236.88	46.60
Croplands/Fallow	638.16	28.18	2255.8	47.01
Dense forests/Plantations	4.66	0.21	27.17	0.08
Water areas	19.29	0.73	304.65	0.13
Savannahs	98.6	3.14	530.81	6.18
Total	2263.29	100	4854.2	100

- **Spatial distribution of urban heat island in Golfe 5 and 7 communes**

The analysis of the spatial distribution of urban heat island reveals an oscillation between -0.25 and 0.2 in the two communes (Figure 5a, Table 3). Fisher test, ANOVA Oneway showed that the variation of the UHI between the two communes was significant ($p \leq 0.05$).

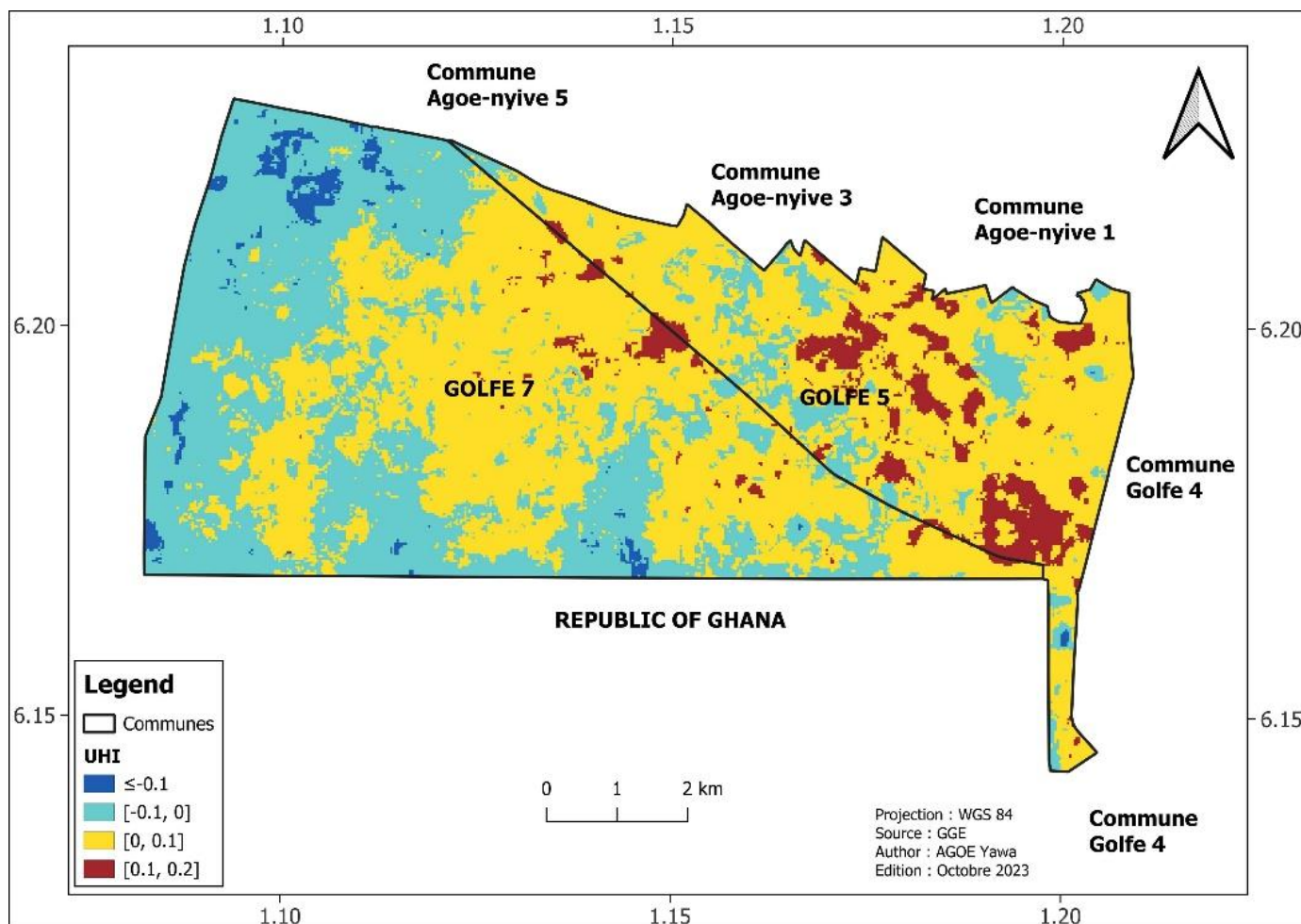


Figure 5. Urban heat island in the Golfe 5 and 7 communes (Source : Google Earth Engine)

Table 3. Proportion of urban heat island by municipality

Communes	UHI	Areas	
		Ha	%
GOLFE 5	≤ -0.1	2.52	0.11
	$[-0.1, 0]$	328.05	14.48
	$[0, 0.1]$	1603.15	70.76
	$[0.1, 0.2]$	331.86	14.65
Total		2265.58	100
GOLFE 7	≤ -0.1	120.93	2.49
	$[-0.1, 0]$	2307.85	47.52
	$[0, 0.1]$	2349.54	48.38
	$[0.1, 0.2]$	78.36	1.61
Total		4856.68	100

(Source : AGOE, 2023)

- **Variation of UHI as a function of land use**

Generally speaking, the hottest areas are represented by buildings/bare grounds. Relatively low temperatures were observed in the area of dense forests/plantations, savannahs, cultures/fallows and water area.

In the commune of Golfe 5, the distribution of UHI (Figure 6) according to land use have shown that the UHI exceeding 0.1 covered a larger proportion in entropized areas (buildings/bare grounds (17.955%) and croplands/fallows (9.29%)). The UHI below 0 was observed in dense forests/plantations (69.10%), savannahs (98.17%), cultures/fallows (90.69%) and water area (71.63%). Statistical tests (Oneway ANOVA) showed that the variation of the daytime temperatures and the night-time temperature between land use in the Golfe 5 commune was significant ($p \leq 0.05$).

In the commune of Golfe 7, the UHI distribution have shown that the UHI exceeding 0.1 covered a low proportion in entropized areas (buildings/bare grounds (2.77%) and croplands/fallows (0.76%)). The UHI below 0 was consistently observed in dense forests/plantations (93.72%), savannahs (75.98%), cultures/fallows (59.27%) and water area (63.87%). Statistical tests (Oneway ANOVA) showed that the variation of the daytime temperatures and the night-time temperature between land use in the Golfe 7 commune was significant ($p \leq 0.05$).

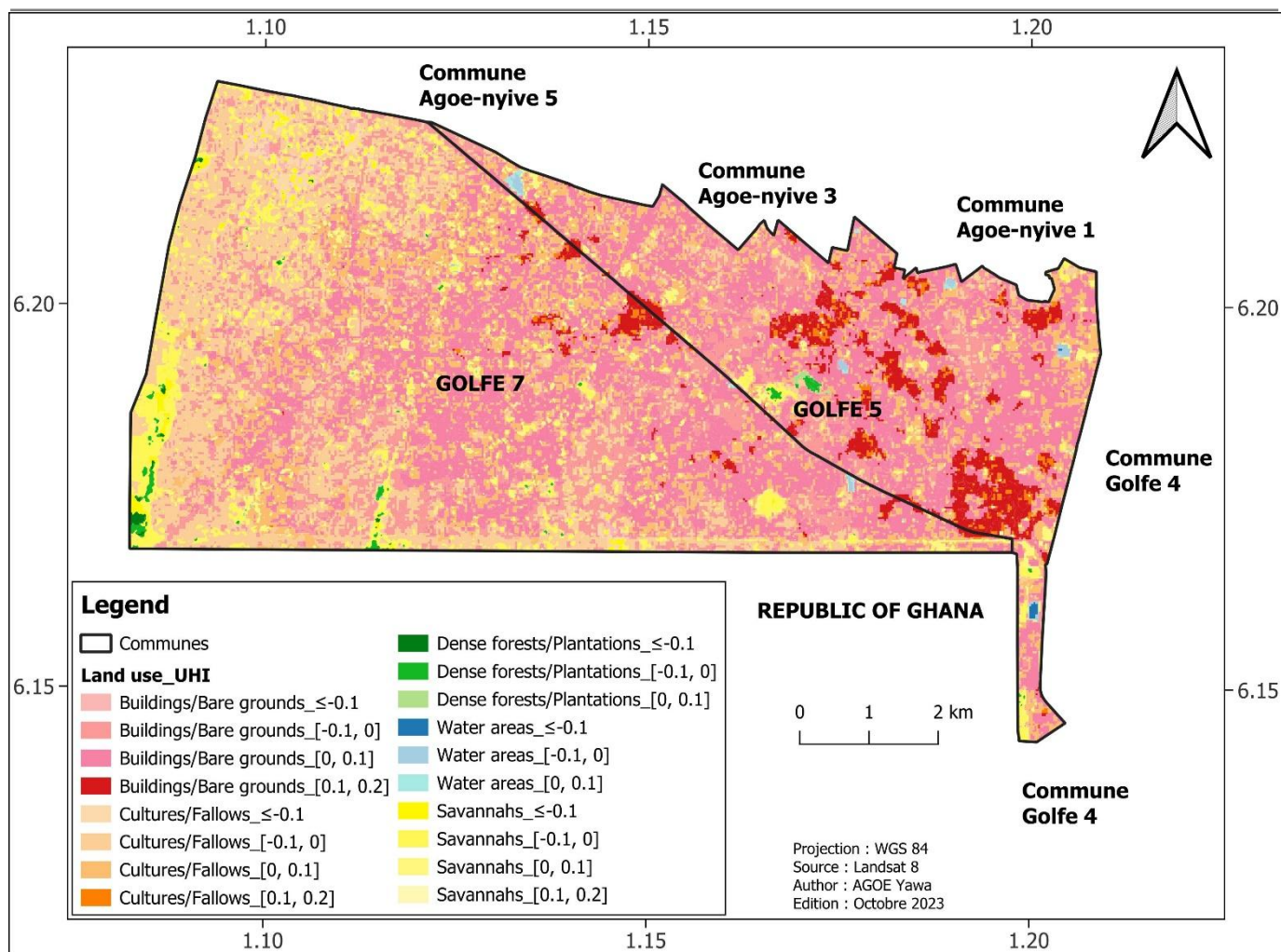


Figure 6. Correlation between UHI and land use units

3.2. Public perception of heat islands

The survey of the resident population of the two communes reveals a diversity of meanings for heat island. For some respondents, heat island is the increase in air temperature (45.45%). For others, it is the result of heat caused by human activity (36.36%). Still others think, it is a phenomenon due to climate change (18.18%). The majority of respondents (53.33%) did not know the definition of heat island, and 13.33% thought that it meant a variation in the temperature of a given area (Figure 7).

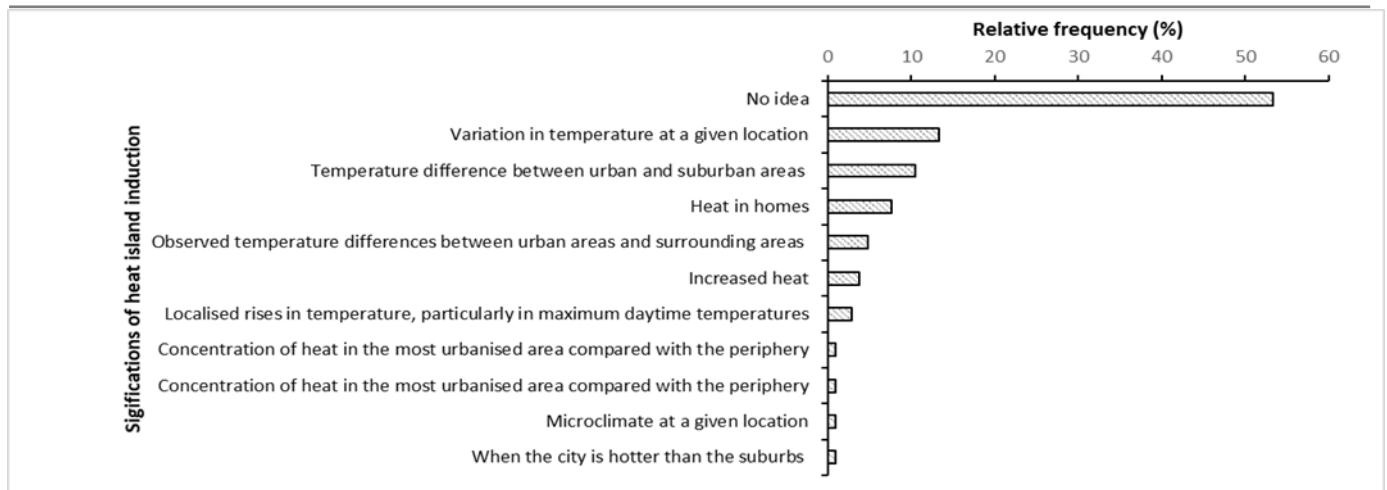


Figure 7. Significance of urban heat island by the local resident population of the two municipalities

According to a sample of respondents, heat island is now manifested through the gradual increase in temperature (63.84%) and changes in seasonality (11.82%). Others had didn't have idea of the concept (4.55%). The heat was felt most at midday (66.97%) and least at night (5.50%). In addition, 62% of respondents felt that heat islands have a negative impact on people's health and contribute to the loss of biodiversity. Others thought that heat islands contributed to the loss of biodiversity (9%) and 2% had no idea. To cope with heat waves, the use of fans (61.47%), air conditioners (8.26%), shading from trees (16.51%), ventilation from building openings (12.84%) and 0.92% have no use at all. In fact, some respondents carry out mitigation actions through private planting (60%), others participate in tree planting on Tree Day (7%) and others do not carry out any actions (33%).

At the municipal level, the public believes that actions to maintain green spaces (if they exist) (47.83%), reforest them (16.91%), monitor them (11.59%) and protect them (11.11%) will contribute to their preservation and sustainable management (Figure 8).

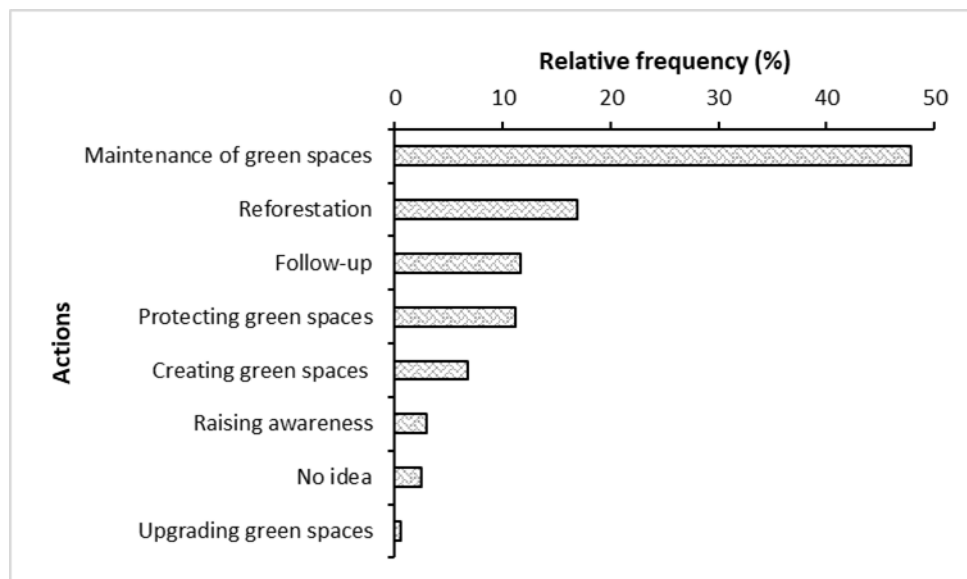


Figure 8. Actions for promoting the preservation and management of green spaces

4. Discussion

4.1. Implications of forestry for the management of urban heat islands

Land use analysis reveals a predominance of building areas/bare soil and croplands/fallow land in both communes. This result is consistent with the work of Polorigni (2019) in Lomé, who reported a predominance of building areas/bare ground. Adeito et al. (2022) found a predominance of croplands/fallow land for their studies in Kinshasa. However, our study highlights a significant difference in the degree of urbanization between the communes studied. Golfe 5 is more urbanized than Golfe 7. This would explain the predominance of built-up areas/bare ground in Golfe 5 commune. The Golfe 7 commune is marked by the predominance of croplands/fallow land. The hottest areas are observed in buildings/bare grounds. This result is similar to Balandi et al. (2025) studies in Kisangani City. The areas of dense forest/plantations, savannahs and water bodies have relatively low temperatures. These results are similar to those of Ghribi and Dahech (2020) and Dousset et al. (2011) for urban areas in central-eastern Tunisia and Paris respectively. This confirms the hypothesis that a reduction in vegetation leads to an increase in temperature. These results highlight the importance of integrating urban forestry into urban planning in order to mitigate the negative effects of urbanization on the local climate.

In the commune of Golfe 5, the UHI exceeding 0.1 covered a larger proportion in entropized areas (buildings/bare grounds (17.955%) and croplands/fallows (9.29%)). But, in the commune of Golfe 7, the UHI distribution have shown that the UHI exceeding 0.1 covered a low proportion in entropized areas (buildings/bare grounds (2.77%) and croplands/fallows (0.76%)). The difference constated between the two communes can be attributed to the increased urbanization and building density in Golfe 5, which favors the accumulation of heat due to the urban heat island effect. This is consistent with the work of many authors (Oke 1982), where temperature variation is influenced by urban sunshine in tropical regions, leading to significant warming during the day. Building areas/bare ground account for a significant proportion of hot temperatures recorded, which corroborates the conclusions of previous studies (Amirtham 2016; Zhang et al. 2009), highlighting the negative impact of urbanization on the local microclimate. The results also indicate that land use plays a crucial role in temperature variation. In contrast, vegetated areas such as dense forests/plantations and savannah show lower temperatures, highlighting their potential role in thermal regulation (Akbari et al. 2001; Esperon-Rodriguez et al. 2022; Loustau 2019). This is consistent with the work of Nowak and Dwyer (2007), who show that tree cover can mitigate the urban heat island effect by providing shade and evaporating water. Implementing tree planting and green space creation programs could not only improve thermal comfort for residents but also contribute to urban biodiversity (Lwasa et al. 2014; Živojinović et al. 2015).

4.2. Populations perception and actions to mitigate urban heat islands

The populations of the communes of Golfe 5 and 7 are aware of the effects of urban heat island and they are taking action to counter the harmful effects. This result corroborates the conclusions of other researchers having worked on temperature variations in Lomé: (Adjoussi 2000; Badameli and Dubreuil 2015; Polorigni 2019). The majority of respondents perceived the heat to be higher at midday and lower at night. This result is consistent with the findings of Somadjago (2019) in the city of Lomé. It shows that heat islands have a negative impact on people's health and contribute to biodiversity loss. To deal with these effects, the majority of respondents resort to the use of household refrigeration appliances, which are sources of greenhouse gas emissions because they run on fossil fuels. Private and community or public planting initiatives would provide greenhouse gas sinks and carbon sequestration to mitigate the effects of heat. In Chad, for example, the population of the urban area of N'Djaména confirms the ecological importance of trees (FAO 2012).

5. Conclusion

Urban forestry helps to reduce heat islands. The municipality of Golfe 5, whose land use revealed a predominance of building areas/bare ground (67.74%) and croplands/ fallow land (28.18%), is more urbanized than the municipality of Golfe 7, with a predominance of croplands/ fallow land (47.00%) and building areas/bare ground (46.60%). The spatial distribution of urban heat island shows uneven variation between the two communes. The hottest areas is observed in the Golfe 5 commune. The hottest

areas are characterized by building areas/bare ground and croplands/fallow land, while dense forests/plantation, savannahs and water areas have relatively low temperatures. Local populations perceive the heat to be more intense at midday than at night. Various actions to adapt to the harmful effects of heat islands have been identified, some of which have co-benefits with measures to mitigate the effects of climate change. The use of satellite images for land surface temperature analysis is insufficient. Future studies will need to use tools that allow for temperature measurement in the field.

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Writing – Review and editorials	Dourma Marra, Akpagana Koffi

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