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Cool city as a sustainable example of heat island management case study of the coolest city in the world

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Abstract Urbanization negatively impacts the urban environment mainly by the production of waste heat from refrigeration systems, although industrial processes and motorized vehicular traffic have also been recognized as additional causes of the urban heat island (UHI) effect. The UHI negatively impacts the residents, with spillover effects for environmental aspects. In urbanized areas, it is a critical factor for air quality management and public health. The UHI and strategies to implement its mitigation are becoming increasingly important for governmental agencies and researchers. The problem is how to deal with UHI effects? Accordingly, the main aim of this paper is to determine the UHI mitigation strategies and their effectiveness in terms of cooling and temperature reduction in cities at the level of urban design. This goal is achieved through exploring the concept of the cool city, as it is the key factor, from the theoretical, analytical, and practical viewpoints, to diminishing the urban heat release. Then, the paper analyzes how the concept of the coolest city in the world (Stuttgart, Germany) is developed and explores a practical approach toward cool cities. Finally, it suggests a set of recommendations to develop the urban environment in Greater Cairo by applying the cool city concept.

Introduction

Urbanization negatively impacts the environment mainly by the production of pollution and the modification of the physical and chemical properties of the atmosphere. Considered to be a cumulative effect of all these impacts is the urban heat island (UHI). Defined as the rise in temperature of any man-made area, UHIs have been indirectly related to climate change due to their contribution to the greenhouse effect, and, therefore, to global warming.

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Therefore, this paper focuses on the cool city concept as it is one of the sustainable solutions for urban heat management and contributes to the development of the visual image of the city.

The research problem

The world is increasingly urban. More than half of the world's population is living in urban areas. The number of urban residents is expected to continue to grow, especially in developing countries. The expanding urban population will require a whole range of infrastructure, services, housing, and jobs, not to mention land. The urban land expansion could threaten land supply, cause growth in the traffic volumes and increased pressure on the environment, and be massively unsustainable for any city.

Accordingly, there is an urgent need to act on a number of indicators that have reached critical levels, notably the UHI, greenhouse gases, water, and biodiversity, of which cities are the main source. In response, this paper answers the following questions:

- What are the consequences of the UHI effect in cities?
- What is the best strategy to cope with heat?
- How will individual cities become a cool city?
- What are the useful design principles to diminish the UHI effect in cities?

Research objectives

The main aim of this research is to determine the main strategies to optimize urban areas regarding the UHI effect at the level of urban design and planning. This goal will be achieved through a group of secondary aims, as follows:

- Reduce the UHI effect for the Egyptian region under current and future climate conditions.
- Develop the visual image of cities by highlighting the importance of urban parks and green open spaces.
- Increase resilience against global warming by the establishment of green corridors at the level of urban design.
- Improve air quality and ventilation in cities through the application of green infrastructure principles.
- Create an attractive urban environment and reduce the temperature of cities through the use of water in the urban landscape.
- Generate applicable measures for urban designers to improve the urban microclimate with a focus on heat.
- Prepare the urban environment for future climate change.

Research methodology

The research methodology is based on three approaches: the theoretical, analytical, and applied studies. The first stage in the methodology adopted for this paper was to identify the UHI and the concept of the cool city. This is followed by an analytical study of Stuttgart City in Germany as it is the coolest city in the world. Next, the paper suggests the design principles of the cool city based on the analytical study to reduce the UHI through a framework to develop the urban environment toward a cool city. Then, it applies this framework to the Egyptian context. Finally, it suggests a set of recommendations to develop the urban environment with a special emphasis on Greater Cairo by the application of the cool city concept.

Research hypothesis

The concept of the cool city can positively impact the UHI for the purpose of achieving sustainable urban development. That is because the cool city has sustainable solutions for urban heat management. Accordingly, this paper assumes that the cool city concept is a positive contribution toward sustainability.

The cool city as an approach to urban heat management

Definition of the urban heat island

The urban heat island (UHI) is defined as "those urban areas where the surface, sub-surface or air temperatures are higher than the corresponding temperatures in surrounding rural areas," [5] due to the many facets of urbanization in cities and towns. Specifically, this effect is caused by a lack of natural evaporative surfaces (vegetation), physical characteristics of the surfaces, such as concrete and asphalt, which absorb rather than reflect solar radiation, human activities that produce heat produced mainly through the actions of heating and cooling plants and buildings, industrial activities, vehicles, etc. "This phenomenon causes a high level of pollutants that alter the radiative nature of the atmosphere and result in surface temperature and atmospheric temperature changes" [4]. In response, a set of strategies exists that can be implemented in order to minimize the negative effects of the UHI, which can be defined as urban heat management; one of these sustainable solutions is the concept of the cool city (Fig. 1).

Definition of the cool city

"The cool city is one of the sustainable urban solutions for the city of tomorrow that depends on the application of the principles of urban heat management. It is the key factor to

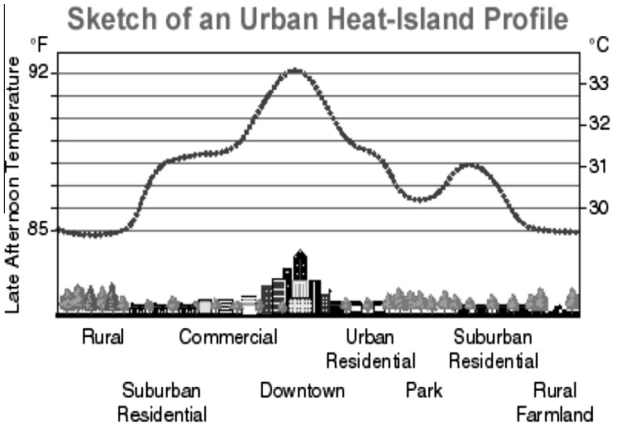

Fig. 1 Sketch of an urban heat island profile. Ref.: M. Giguère, Urban Heat Island Mitigation Strategies, the Institute national de santé publique, 2009.

diminishing the urban heat release, creating solutions of future climate change by reducing the volume of global emissions, and creating smart growth and cool community scenarios'' [5].

Objectives of a cool city

There are many objectives of a cool city on the level of urban planning and design, as follows:

1. Support the implementation of green infrastructure and green spaces to improve air quality and lower greenhouse gas emissions to achieve environmental sustainability.
2. Help us clean our air, reduce our carbon footprint, and lead toward a stable climate future.
3. ''Reduce energy use: Trees and vegetation that directly shade buildings decrease demand for air conditioning.
4. ''Reduce pavement maintenance: Tree shade can slow deterioration of street pavement and decrease the amount of maintenance needed'' [2].
5. Promote cooling in urban environments to reduce UHI.

Cool city applications in urban design and planning

''UHI Project is developed in 8 of the most relevant metropolitan areas and Mega Urban Regions of the Central Europe cooperation programme; one of them is Stuttgart city. UHI Project aims at developing mitigation and risk prevention and management strategies concerning the urban heat island (UHI) phenomenon. This activity is supported by the Central European Programme and the European Regional Development Fund'' [21].

Accordingly, this section will focus on a case study of Stuttgart City as it has adopted a number of sustainable solutions to solve the environmental problems it was facing through applying the concept of the cool city. The aim of this section is to conclude the application areas at the level of urban design to be applied in the Egyptian context.

Stuttgart

Stuttgart is located in the southwest region of Germany and it is the coolest city in the world. ''Stuttgart's climate planning strategy is seen as one of the best examples of heat island management in the world. Stuttgart has been planned not only to respect and protect nature, but to exploit how natural wind patterns and dense vegetation can actively help the city to reduce its problems of overheating and air-pollution'' [18].

Climatic conditions

''Stuttgart is a city well known for its industrial productivity and affluence, and is often referred to as Germany's 'cradle of the automobile'. It is defined as much by its dense, convivial city-centre as by its lush surrounding hillsides. Over 60% of the city is covered in green. Vineyards, forests and public parks both surround the city, and, in places, stretch down the hillside to touch the center. This unique landscape feature and the particular topography of the region are used to ensure an attractive and comfortable urban environment for Stuttgart's residents. Since the city lies in the valley basin, the city cannot easily get rid of its own heat and it stays trapped within the city'' [18]. In consequence, Stuttgart has followed an urban—compact—green strategy to be the coolest city in the world, as is described below:

Green corridors

''Stuttgart is a forerunner in the protection of green spaces. Using green ventilation corridors and construction bans at strategic places, Stuttgart has not only protected its climate with winds that hinder overheating. It has also improved air quality and increased resilience against global warming. With the support of detailed local climate maps, Stuttgart has stopped planned construction totaling over 60 hectares in recent years [16].

''At night, clean air sweeps down from the surrounding hills and runs through a series of 'ventilation-corridors' which have been kept open as wide, tree-flanked arteries within the city's street infrastructure'' [18] (Fig. 2).

Green infrastructure

''The correct application of 'green infrastructure' can be used to combat the urban heat island effect. In Stuttgart's case, this is made part of urban policy in such a way that it complements other macro layers which offer environmental benefit, increasing bio-diversity and air-quality'' [18]. ''A new method for the strategic planning of green infrastructure investments, directed towards the improvement of essential linkages between green spaces and places of employment and living. The essential linkages in particular for commuters within Stuttgart Region are the 'development axes' mainly along the river valleys like the Neckar, the Rems and the Fils'' [3]. There are many examples for green infrastructure applications, as follow:

''The Neckar river cycle path'' [3]. The Neckar river cycle route is an important artery for commuters as well as for tourists in the Stuttgart region and it is considered one of the green infrastructure investments in the city. The new route sections allow green, safe, and efficient transportation between industrial and commercial centers and residential and leisure areas in the Stuttgart Region. In addition, the cycle route provides a way to include exercise in the daily life of individuals and the greening and landscape quality along the river. This investment is part of a green network based on the findings of the ''Masterplan Neckar Landscape Park,'' the strategic planning tool for green infrastructure investments in the region (Fig. 3).

Urban parks. ''Stuttgart is one of Germany's greenest metropolitan cities through working towards the sustained development of the city that is based on the principle of cool city'' [8]. ''More than 60% of Stuttgart's area is green area. The city has 65,000 trees in parks and 35,000 along streets. Since the 70s, the city has integrated green areas into a large green 'U,' which now makes it possible to go through park environments all the way from the central royal gardens to the forests at the city's edges'' [2].

The green ''U'' is an urban massive public park in the shape of a U. Among the park planners were ecologists and social scientists who aimed at a more ecological approach for the Rosenstein Park, encouraging contact between people and nature [14]. Additionally, the park contributes significantly to making the city cooler, as the cooling of cities is one of the characteristics of a green area (Fig. 4). Besides that, Stuttgart

Fig. 2 Ventilation corridors in Stuttgart. Ref.: A. Svane, sustainable cities, Stuttgart, Cool city, 2010.

Fig. 3 (a) The Neckar river cycle path. (b) A place to pause. (c) The Neckar valley cycle path. Ref.: The Neckar valley cycle path, http://www.neckar-magazin.de/english/activities/neckar-valley-cycle-path/index.html, 2012.

has a lot of parks such as the Mansion Mountain Park, the Wilhelma, the Leibfried Garden, the Waiting Mountain, and the Killesberg Elevator Park.

Vegetation/urban compact green. Stuttgart's land-use plan is urban-compact-green, of which a good example is the project of Stuttgart 21: "it is a railway and urban development project in Stuttgart, Germany. The concept depends on the replacement of the current terminal station by an underground track through station. The Stuttgart 21 project was a sustainable vision in urban design and planning due to its objectives of making the city more sustainable and cooler through maintaining the continuity of Rosenstein Park by transforming the present rail tracks into green urban spaces (Fig. 5). It is also possible to link the green areas of the park through passages of so-called green connections" [17]. "As for sustainability, huge skylights and light wells pump natural day lighting down onto the subterranean tracks, and with the use of photovoltaics on a nearby building, the whole complex is virtually net zero" [8]. On the other hand, most of streets in Stuttgart are scarcely planted; sometimes trees have been planted just on one side of the street, sometimes not at all, or with a lot of space in between. Thus, urban compact green is a key factor to diminishing the urban heat release.

Fig. 4 The Rosenstein Park in Stuttgart, Germany. Ref.: http://www.diakonie-wuerttemberg.de/aktion-und-spende/diakonie-pilgerweg/texte-zum-pilgern/unser-abendgebet-steige/.

Fig. 5 (a) The old tracks in Stuttgart Hbf. (b) The project of Stuttgart 21. (c) The continuity of the park above the train station. Ref.: Die Nächste Haltestelle, 2013, http://nikhilpress.wordpress.com/2013/02/22/the-big-dig-stuttgart-edition-only-with-more-controversy-and-rioting-and-about-rail/ June, 2014.

Cool buildings. Cool buildings are those buildings that adopt the concepts of passive cooling. "Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or nil energy consumption" [13]. Stuttgart City is the leader in the application of the cool building concept due to the establishment of the new Stuttgart City library, which is the coolest library in the world. "It is a landmark on the city's skyline. In order to achieve the room's characteristic effect, the architects opted for a particularly high-quality material, the materials specified give a durable and long-lasting solution" [20]. The structure features a natural cooling system and reflective materials (Fig. 6). Another example of a cool building is the new Stuttgart main station building. It depends on smart zero energy concepts that create intelligent use of the existing natural energy resources to activate the building and to improve the comfort of the users.

Green roofs

"Stuttgart is one of the leading green roofs cities in the world. Since 1986, Stuttgart has been running a financial support program for green roofs and has set requirements for all new roofs below 12 degree slope must have green roofs. Since 1993, all new buildings in Stuttgart have been greened" [9] and it has subsidized more than 300,000 square meters of green roofs.

Fig. 6 Stuttgart new city library. Ref.: The world's coolest libraries, 2013, http://prestige-singapore.com.sg/2013/04/worlds-cooles libraries#.U6vs4rcU_IU July, 2014.

For example, the GENO-Haus bank building features green roofs, seen below, along with the First Green Roof Bus in the world. The public transportation system of Stuttgart greatly promotes sustainability by applying the green roof concept to the system's busses: "it demonstrates the clear message how environmentally friendly the entire public transportation system in Stuttgart is. Besides leading the world with the most advanced technology in trains and busses, the train stations, bus stops, rail road tracks or any type of building undergo a long process of research to maximize the environmental benefit and to reduce their foot print" [7]. "Although green roofs are most cost intensive to construct, heavy in weight with deep soil profiles, and maintenance intensive, they have many benefits; they are mainly installed for environmental performance, visual improvement, the air will be more clean, the apartments under the roof of the building will no longer feel the summer heat and maybe the most important thing is the removal of the greenhouse effect" [19]. Green roofs can maintain cooler indoor temperatures. Green roofs, green walls, and green railroad tracks are an essential part in any construction to help cities to be cooler (Fig. 7).

Urban water

"Water can reduce temperatures by evaporation, by transporting heat out of the city and as a buffer that slowly absorbs the heat. Water applications in general are more effective when water is moving or dispersed as done by a fountain. The effect of cooling by water evaporation depends on the air flow that spreads the cooled air through the city. And flowing water has a larger cooling effect than stagnant water; dispersed water like from a fountain has the biggest cooling effect" [11]. As a consequence, Stuttgart depends on the use of fountains in the urban area and numerous lakes are visible along the Rosenstein Park (green U park), which is located in central Stuttgart. For example, "Stuttgart is having the second largest source of mineral water in Europe" [15]. And "the two massive fountains that grace the park in front of the New Palace in central Stuttgart are quite beautiful. And they are huge. They date back to 1863" [10] (Fig. 8).

Materials

Accumulation of heat occurs in urban areas because higher levels of solar radiation are absorbed by the materials used in cities. "One aspect of the accumulation of heat in hard materials is depending on the colour. A light colour will reflect

Fig. 7 (a) Green roofs in Stuttgart. (b) The GENO-Haus bank building in Stuttgart. (c) The first green roof Bus in the world. Ref.: Green Roof Service LLC, http://www.greenroofs.com/content/apr-GRS-052411.htm, 2011.

Fig. 8 (a) North fountain in front of the new palace. (b) Fountain in the Rosenstein Park. (c) Lakes in the parks called Mineralbäder in Stuttgart. Ref.: Is started in Stuttgart? 2012, http://kingdomhistory.blogspot.com/2012/05/fountains-at-schlossplatz.html.

solar radiation, while a dark colour absorbs it. This reflectivity is called albedo by climatologists. Another aspect is the time in which a material releases heat. Materials like brick have a long time lag, which results in radiating heat into the air during nighttime until sunrise (Fig. 9). Instead of cooling the hard materials, heat is accumulated. Not only at the surface, but also in the third dimension, facades, the heat is absorbed. That's where most of the facades in Stuttgart benefit from light colours" [4] (Fig. 10).

Environmental management concept

"Stuttgart established an environmental office with the task to evaluate planned buildings' effects on the local climate, and develop control systems to protect key areas and increase the green spaces in the city. The environmental office could use the support of national and regional legislation protecting green spaces, and national building laws that after a 2004 revision integrated sustainability principles and even paragraphs on green spaces and air quality" [16]. Some of the recommendations are as follows:

"In ventilation corridors for cold air, and in other open areas with large significance for the climate, no new construction is allowed. In built areas with large significance for the climate, increased vegetation and green space are recommended. In addition, the following principles guide planning:

- Green spaces shall surround buildings and larger interconnected green areas shall be protected and created,
- valleys, hills, and hillsides shall not be built up,
- in connection with industrial building, air pollutants in the surrounding settlements and urban sprawl shall be avoided" [16].

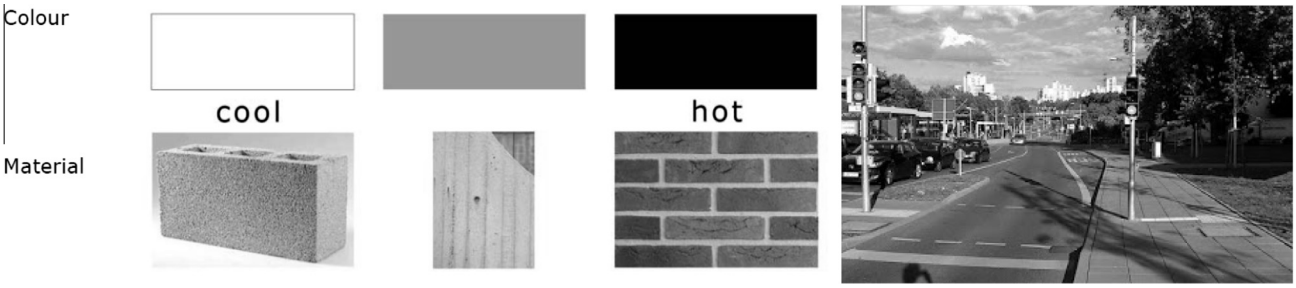

Fig. 9 (a) Heat absorption depends on the color and the materials used in pavement. (b) Albedo is used in the pavements. Ref.: L. Kleerekoper, Design Principles for Urban Heat management in the Netherlands, Graduation Msc., 2009, p. 16.

Fig. 10 The impact of color and material on the urban heat island. Ref.: M. Giguère, Urban Heat Island Mitigation Strategies, the Institute national de santé publique, 2009.

Framework for urban heat management

This section discusses measures in the form of a framework that will diminish the accumulation of heat in urban areas. Cities can mitigate their UHI effect by a set of planning actions, which is considered one of the main strategies of the cool city. These strategies can be summarized as the following: vegetation, urban water, green corridors, green infrastructure, and green roofs and materials (Fig. 11).

Case study on Greater Cairo, Egypt

This section will deal with Greater Cairo to document the most important problems that face urban environments and are considered the main factors in raising the UHI. Following that, the section will suggest a set of future recommendations based on the sustainability framework, which is, based on the results of the study, to make recommendations for ways to reduce the UHIs and make Greater Cairo cooler.

The objectives

The main goal of this study is to reduce the urban heat effect on the urban environment in Greater Cairo through a set of sub-targets, as follows:

- To improve air quality through oxygen production and vegetation.
- To reduce energy demand for air conditioning.
- To improve water quality.
- To develop the visual image of the urban environment.

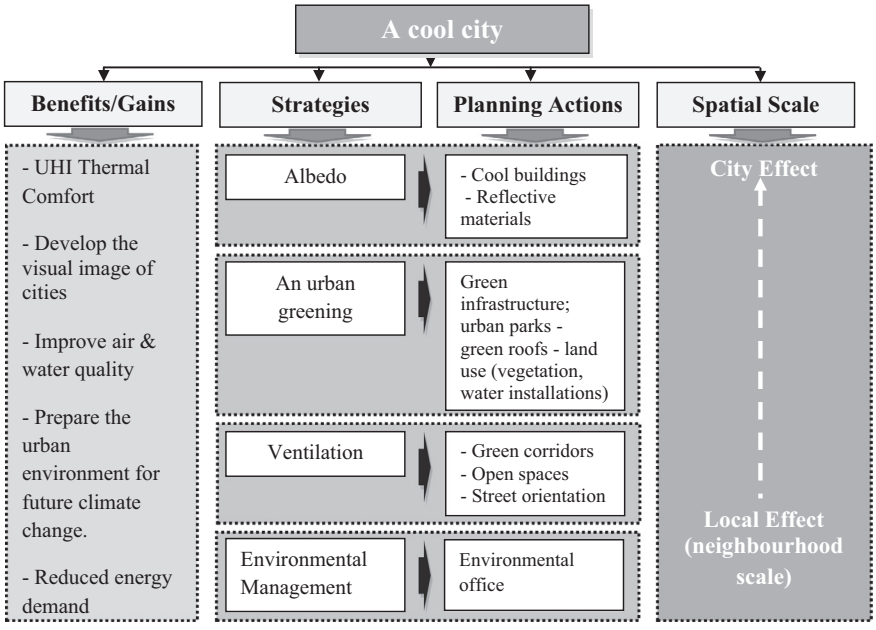

Fig. 11 A cool city – framework. Ref.: The author.

Climatic conditions

"Greater Cairo climate's is a hot desert climate and generally dry. The temperatures are hot or very hot in summer days and warm or mild in winter days, but it does have high humidity levels in summer due to its location by the Nile River (Fig. 12). Cairo is the capital of Egypt and the largest city in the Arab world and Africa; with more than 6 million people" [1]. There are many additional factors that contribute to raising the UHI in Cairo, such as the following:

- A high density of population due to rapid growth of urbanization and
- environmental pollution due to old vehicles, traffic congestion, and unsustainable urban transportation.

Documentation of the problems confronting Greater Cairo's urban environment

"Greater Cairo is the largest metropolitan area in Egypt and the largest urban area in Africa, consisting of Cairo, Giza, Shubra el-Kheima and Helwan" [6].

Greater Cairo is experiencing problems that prevent making it a cool city. The focus of the study area is on Greater Cairo, comprising the area that is surrounded by the ring road.

Urban problems

These include a lack of the presence of parks. A certain number of parks do exist, such as, Al Azhar Park, Al Asbakia Garden, El Orman Garden, and El Fustat Garden, but these represent a small percentage of Greater Cairo's area, and overall the city is experiencing a decrease in the presence of lakes and green spaces that help to improve air quality (Fig. 13).

There are a lot of informal settlements in Greater Cairo, where every middle and upper class district of the city is surrounded or neighbored by a slum. These places were built without planning and have little or no planned infrastructure or green spaces and these informal settlements feature very crowded buildings that contribute to raising the UHI effect (Fig. 14).

Greater Cairo is largely absent of green corridors, which has the effect of contributing to raising the UHI, whereas the concept of urban green corridors can contribute to the improvement of urban environmental quality. Further, the creation of these corridors promotes the image of the city, making it more attractive and competitive.

Even though Cairo is located to the east of the River Nile, a number of commercial uses contribute to raising the UHI. For example, the existence of restaurants on the river banks hinders the available vistas and prevents the air movement in the streets that are perpendicular to the Nile, as well as contributing to a lack of open and green spaces that overlook the Nile. In addition, the Nile valley is overcrowded (Fig. 15).

There is an absence of applications toward sustainability at the level of buildings, streets network, and the streetscape. For example, there is a lack of green roofs and green walls, and the materials that are used in streetscape are unsustainable. This is especially true in the pavements, and is made worse by an absence of landscaping along the sidewalks and street corners, which leads significantly to the absorption of heat and negatively affects the environmental aspects and urban image (Fig. 16).

Greater Cairo's main problem is overcrowding, with the attendant effect that there is a great problem with all kinds of pollution, including that of air, noise, and land. This is also a direct result of the many factories located around the city. Also, one of the worst problems in the city is that of garbage and refuse collection; there is no municipal garbage collection in Cairo, where many tons of waste are routinely left on the streets. All these negative contributors are in addition to traffic congestion, unsustainable urban transportation, and the burning of agricultural "waste," mostly in the form of rice straw, which negatively affects the air quality and the UHI (Fig. 17).

From the previous study, the paper concluded that, Stuttgart is one of Germany's greenest metropolitan cities through working towards the sustained development of the city that is based on the principle of cool city. Therefore, the next section will analyze the contrasting of the differences between Stuttgart case and Greater Cairo case, at the applications for urban heat management, to help in drawing the future recommendations for developing mitigation and management strategies concerning the UHI phenomenon in Greater Cairo.

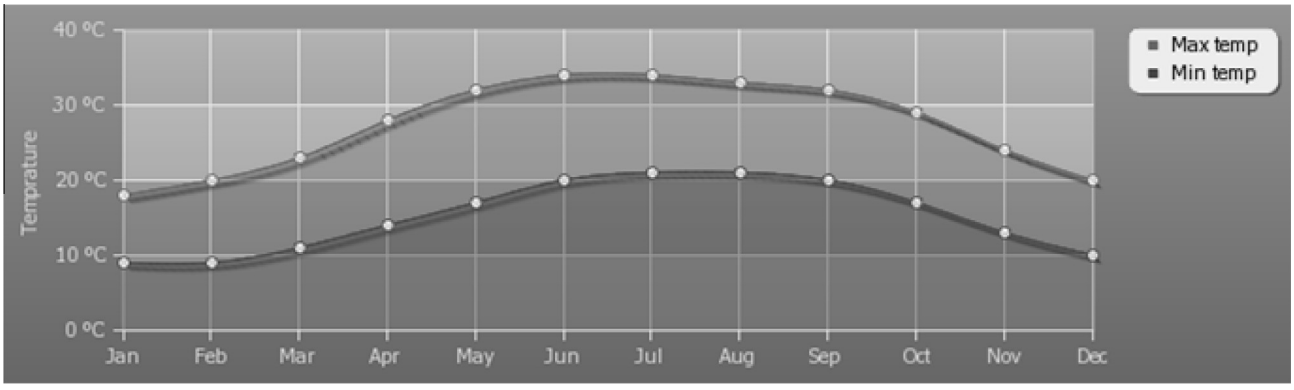

Fig. 12 Average high and low temperatures in Greater Cairo. Ref.: Average temperatures in Cairo, Egypt, 2013. http://www.weather-and-climate.com/average-monthly-min-max-Temperature, Cairo, Egypt, July, 2014.

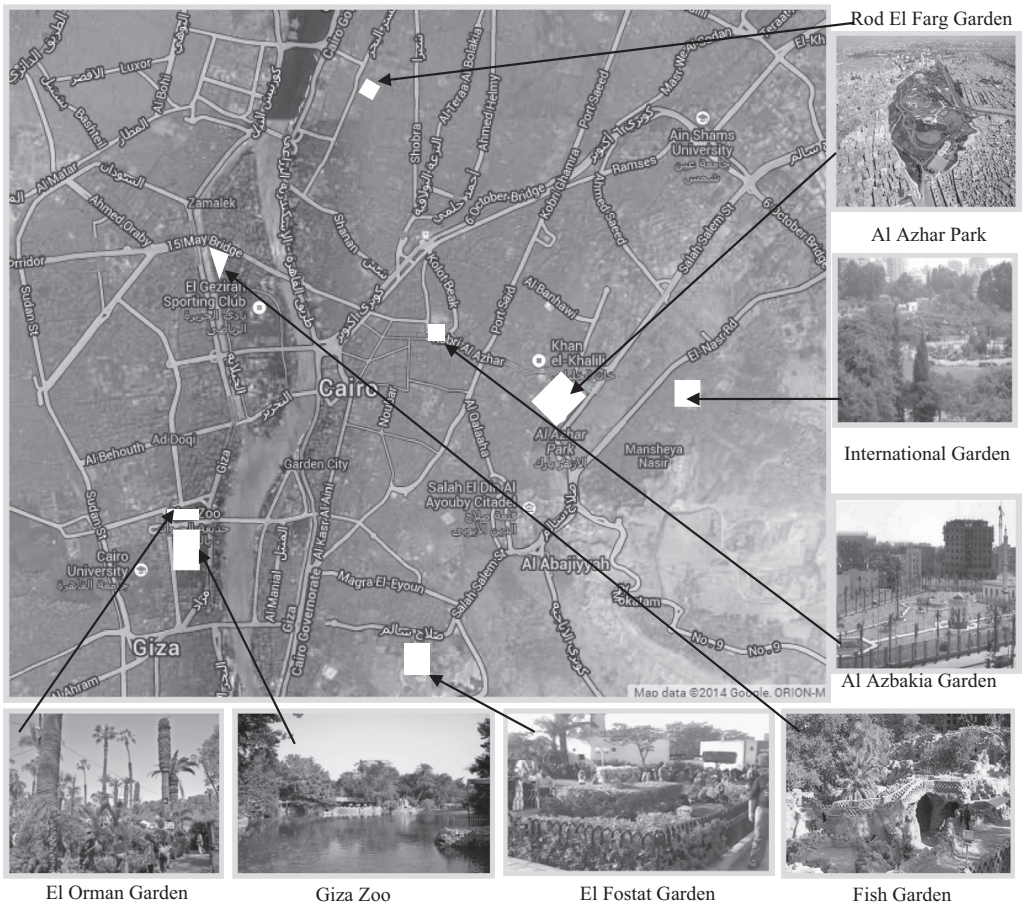

Fig. 13 Green spaces in Cairo. Ref.: Google Earth July, 2014.

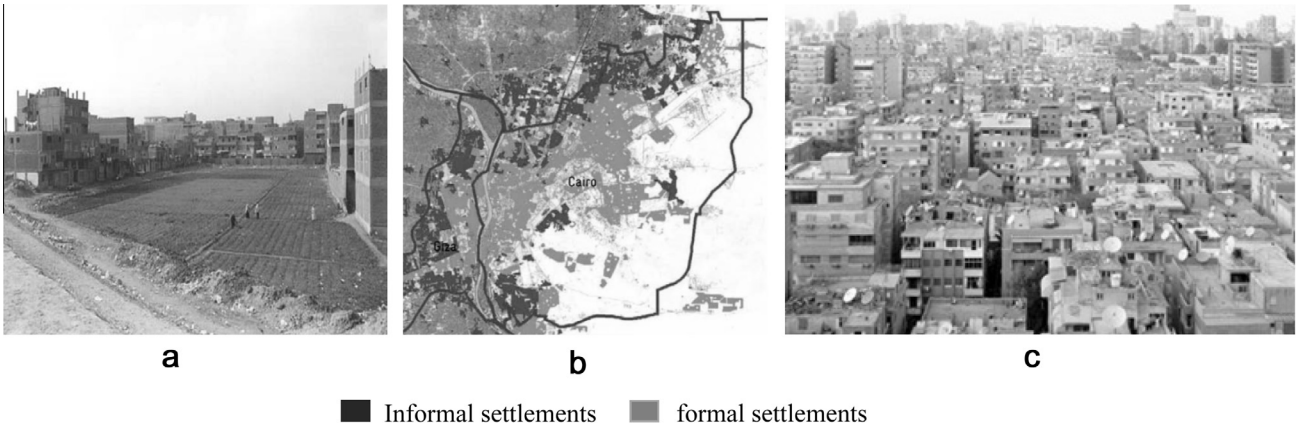

Fig. 14 (a) Informal settlements in Cairo. (b) Informal settlements. (c) Formal settlements. Ref.: J. Stryjak, About Cairo and its informal areas http://www.citiesalliance.org/sites/citiesalliance.org/files/CA_Docs/resources/Cairo's%20Informal%20Areas%20Between%20Urban%20Challenges%20and%20Hidden%20Potentials/CairosInformalAreas_Ch1.pdf, 2008.

Future recommendations

Future recommendations for developing mitigation and management strategies concerning the UHI phenomenon in Cairo depend on the cool city framework, which is deduced from the theoretical and analytical studies. These recommendations can be divided into four main sections, as follows:

- Albedo:

Cool buildings

– Promote the use of buildings that have reflective materials and natural cooling systems.
– Create a number of zero energy buildings, which, because such buildings should depend on natural ventilation, require no energy for cooling and heating.
– Enhance buildings that have the applications of passive ventilation to reduce the dependence on air conditioning.

Fig. 15 (a) Cairo' streets, Asphalt paved roads have thermal. (b) Overcrowding the Nile valley and radiative properties that promote a high heat release. Ref.: The author & David A., 2013, City of mirages, http://affordablehousinginstitute.org/blogs/us/2013/08/city-of-mirages-part-2-geography.html.

Fig. 16 (a) Absence of green roofs. Ref. J. Stryjak, About Cairo and its Informal Areas, 2008. (b) Conventional pavement. Ref.: The author.

Fig. 17 (a) Traffic congestion. (b) Smoke rises from burning garbage in downtown Cairo on October 20, 2011. Ref.: David A., 2013, IBId & El Dahan M., 2011, industry news, http://www.compositology.com/news/industry_news/egypt-rice-hull-pollution/ July, 2017.

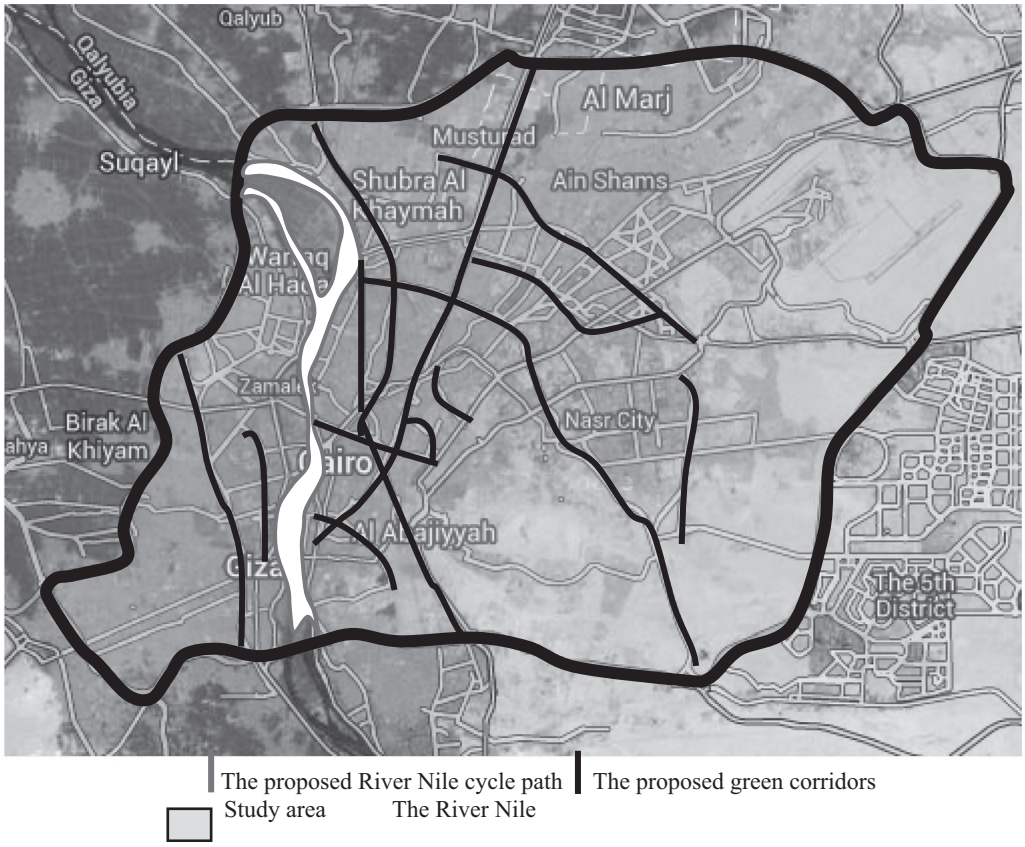

Fig. 18 The proposed River Nile cycle path. The proposed green corridors. Study area. The River Nile. Ref.: The author.

Fig. 19 Sample images proposed green corridors. Ref.: Chinatown Green Street, http://www.asla.org/greenstreet/index.html, July 2014. M. Roth, Streetsblog, 2009. http://sf.streetsblog.org/2009/11/13/portlands-greenstreets-program-a-sterling-best-practice-model/, July 2014.

Reflective materials

- Encourage the use of high-albedo pavements to reduce the ambient temperature of the city.
- Change the color of pavement, roofs, and facades through using materials with light colors.

• An urban greening:

The River Nile cycle path

– Establish a green route on the Nile banks for pedestrians and cyclists and provide this route with a sustainable streetscape that includes such features as solar lighting, vegetation, sustainable materials in floor finishings that reflect the sun's radiation, recycled or renewable materials in route furnishing, and large trees to provide shade for pedestrians.


Fig. 20 Imbaba Airport Garden. Ref.: The opening of Imbaba Airport Garden, 2014, Nile youth. http://www.shbabalnil.com/?p=109371 and Ref.: The opening of Imbaba Airport Garden, 2014, el-Yom Elsabea http://www1.youm7.com/News.asp?NewsID=1430749&#.U82ecbcU_IU.

Urban parks

- Increase urban parks through the creation of a main park in the heart of Cairo or an urban park network, the development of which requires a group of urban planners and urban designers.
- In order to generate cooling, water should be integrated in parks and should be combined with green features such as parks and fountains.
- Large trees should be planted to provide shading, plus they are important in mitigating the UHI effect.

Vegetation

- Increase the city's total vegetation, along transportation corridors, on public property (parks, school yards, playgrounds, etc.), and on private property (residential, commercial, and industrial buildings, etc.).
- Promote green walls to improve the energy efficiency of buildings.

Green roofs

- Encourage the use of green roofs in transportation vehicles.
- Promote green roofs to improve the air quality and contribute to the esthetic integration of buildings in the landscape.

Water installations

- Encourage the integration of water installations into the landscape to enhance urban design and thereby minimize environmental degradation, improve and recreational appeal and reduce UHI effects.
- Conserve water resources through reuse and system efficiency to improve the urban climate.

• Ventilation:

Green corridors

- Transform some of Cairo's streets into green corridors to improve the urban environmental quality and to promote the image of the city, making it more attractive and competitive.
- Improve air quality through using green ventilation corridors and to minimize heat gains in urban environments.
- Enhance green corridors to add green space to the city and to connect neighborhoods with nature.
- Promote plantings between the curb and sidewalk where the concept of green corridor will promote the installation of landscaped sidewalks.
- Corridors can be in a wide variety of sizes, widths, compositions, and structures. There are many constraints such as cost or existing barriers for corridor width, but the final scope of such a corridor really depends on the focal species.

Open spaces

- Land use planning should promote water installations in open spaces (waterfalls, fountains, and pools), as such a ventilation strategy can further increase cooling.
- Improve the accessibility and linkages between open spaces.
- Cool our cities by increasing the access to nature.
- Encourage the protection, conservation, and maintenance of the environment in the design and operation of open spaces.

Street orientation

- Promote the thermal comfort of city dwellers through promoting good wind circulation.
- Promote ventilation in buildings and streets in the summer months, which will help maintain a comfortable thermal environment.

• Environmental management:

- The government should establish an environmental office with the task of evaluating the planned buildings' effects on the local climate, and develop control systems to protect key areas and increase the green spaces in the city with responsibilities relating to the protection and enhancement of the environment.
- Focus on good transportation planning, which is essential to minimize heat gains in urban environments.
- Reduce the production of heat by encouraging the use of sustainable modes of transportation and renewable energy and energy-efficient appliances and equipment.

Table 1 Analysis of contrasting the differences between Stuttgart case and Greater Cairo case, at the applications for urban heat management.

Climatic conditions	Stuttgart has a mild, temperate climate with warm summers. Wind speeds throughout the city are generally low, which along with the UHI effect, contributes to poor air quality	Greater Cairo climate's is a hot desert climate and generally dry
Green corridors	Stuttgart used green ventilation corridors and construction bans at strategic places 	Greater Cairo is largely absent of green corridors 
Green infrastructure	The improvement of essential linkages between green spaces and places of employment and living. And the use of sustainable urban transportation, vegetation, green roofs and cool buildings	The absence of landscaping along the sidewalks and street corners, which leads to the absorption of heat. Besides unsustainable urban transportation which negatively affects the air quality and UHI
The river cycle path	The Neckar river cycle route is considered one of the green infrastructure investments in the city	The existence of restaurants on the riverbanks contributes to a lack of open and green spaces and prevents planning of The river cycle path
Urban parks	More than 60% of Stuttgart's area is green area	Greater Cairo is experiencing a decrease in the presence of lakes and green spaces
Vegetation	Green spaces were created throughout developed areas to facilitate air exchange 	There are informal settlements, These places were built without planning and have no green spaces 
Cool buildings	Stuttgart is the leader in the application of the cool building concept due to the establishment of the new Stuttgart City library, which is the coolest library in the world	There is an absence of applications toward sustainability at the level of buildings. However, Cairo starts to apply a concept through GPRS that is a sustainability assessment rating system, which is directed only for buildings
Green roofs	Stuttgart applied the green roofs concept on the buildings and the public transport 	There is a lack of green roofs and green walls 
Urban water	Stuttgart depends on the use of fountains in the urban area and numerous lakes are visible along the Rosenstein Park	There is a lake of using water elements in urban area
Materials	Most of the facades in Stuttgart benefit from light colors 	The materials that are used in streetscape are unsustainable, which leads to the absorption of heat 
Environmental management concept	Stuttgart established an environmental office with the task to evaluate planned buildings' effects on the local climate	There is an absence of establishment of the environmental offices

Ref.: The author.

A proposed design strategy

The proposed design strategy for Greater Cairo offers an opportunity to achieve a cool city and describes the modifications that will contribute to reducing the UHI effect (Fig. 18). The study area is the area that is surrounded by the ring road.

This design strategy suggests to convert some of the streets to green corridors, especially the streets that are directed toward the north and north-west, such as Ahmed Helmi St., Shubra St., El-Gomhoreya St., 26 July St., Sheriff St., Mahmoud Farid St., Mgra El-Eyoun St., El-Khyalah St., Al-Qalaaha St., and the ring road. Then the strategy suggests to create a cycle path on the banks of the River Nile. The proposed design for the cycle path and green corridors encourages the planting of vegetation (Fig. 19).

Also, the design strategy encourages the establishment of urban parks that help to reduce the UHI; this requires a group of specialists in the field of urban planning and design. For example, the establishment of Imbaba Airport Garden; its design includes "6 greeneries on its ends colored concrete paths and an industrial water lake representing 30% of the garden total area. Besides, it has waterfalls, horizontal and vertical waterwheels, boats land anchors, a lighthouse, 7 pedestrians linking the garden both sides" [12] (Fig. 20).

Besides that, the design strategy suggests the use of green roofs and solar cooling panel to keep buildings cool in bright sunlight by radiating heat out to space and cutting the need for energy-intensive air conditioning (see Table 1).

Conclusion

In recent decades, urbanization and regional climate changes have been occurring rapidly on a worldwide scale. Of the many aspects that are influencing the quality of urban life, one of the most essential aspects is that of the microclimate of an urban area. In these circumstances, the value of the urban heat island (UHI) has probably increased due to a variety of factors: building styles, height, materials, and human activities; more traffic, more industrial activities, higher energy consumption and climate change. Accordingly, UHI mitigation strategies have been implemented in various sustainable cities around the world. One of these strategies is the concept of the cool city. Thus, this paper deals with this concept through a theoretical study and an analytical study of Stuttgart City in Germany, as it is the coolest city in the world. Then, the paper suggests a framework to direct urban designers and planning toward a cool city through reducing the UHI effect. After that, the paper suggests a set of future recommendations to deal with the UHI effect in Greater Cairo at the level of urban design and planning. Then it suggests the proposed design strategy through which Greater Cairo can achieve a cool city, specifying the modifications that can contribute to reducing the UHI effect. Finally, the paper concludes that, to reduce the UHI, strategies of the cool city should be taken into account. These strategies include identifying opportunities for urban greening, making buildings more energy-efficient, and following the concept of the urban green corridor, which contributes to the improvement of urban environmental quality. Further, the creation of these corridors promotes the image of the city, making it more attractive and competitive. The study also recommends the establishment of an environmental office and the use of reflective materials in buildings and pavements to reduce the ambient temperature of the city. If implemented in a systematic manner, all of these strategies stand a good chance of reducing the ill effects attendant upon the occurrence of UHIs in the built urban environment.

Conflict of interest

None declared.

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