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THE URBAN HEAT ISLAND OF NAIROBI

by

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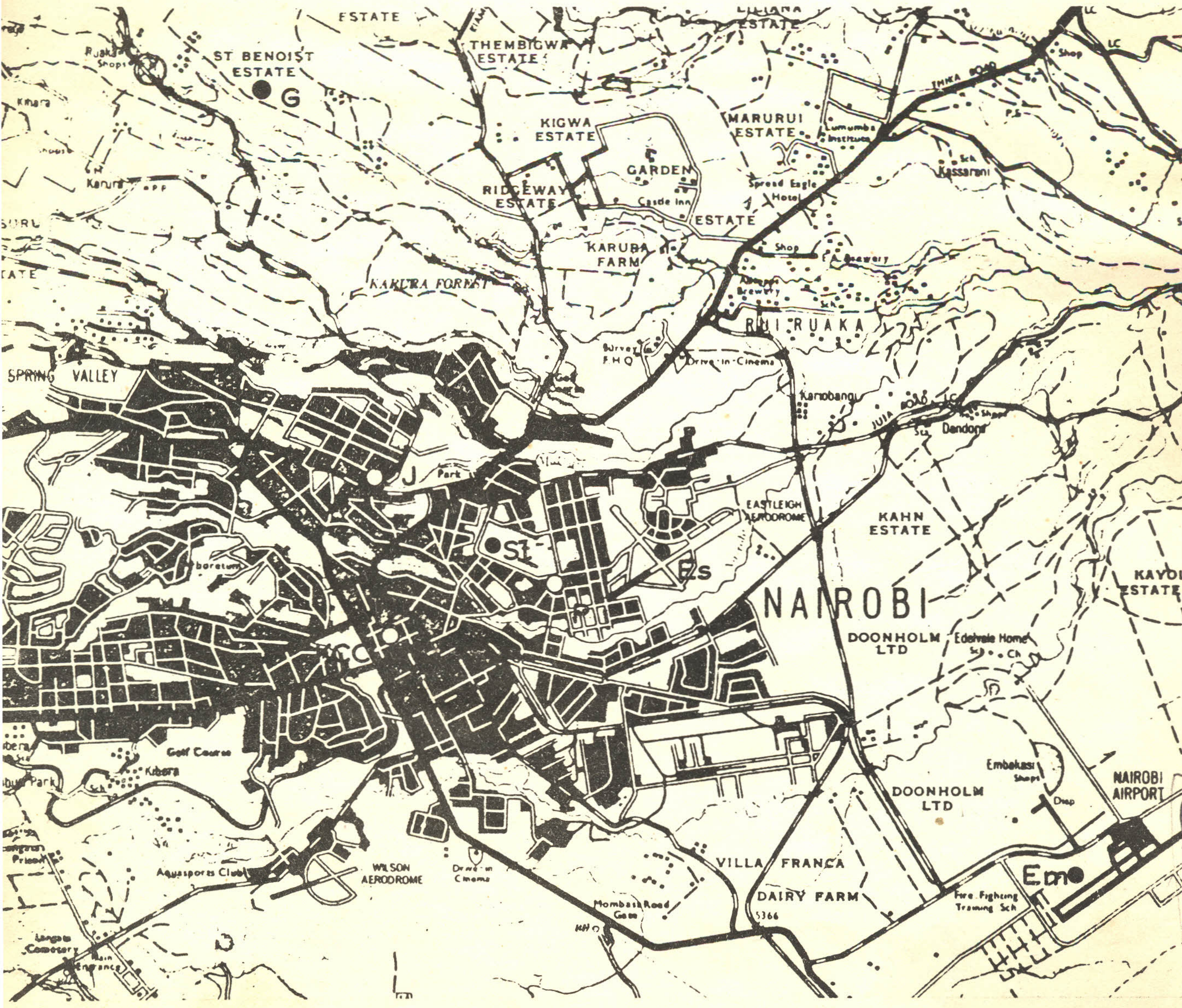


For many years now, the phenomenon of the urban climate has been well observed and described by several authors (Peterson 1969). As one of the most significant observations, the so-called "heat island" could be identified as more than a merely topographic anomaly.

It is now generally accepted that 1) urban development leads to a typical rise of temperature even under quite different topographic and climatic conditions (for the temperate latitudes: Chandler 1965, Bornstein 1968, Nicholas 1971; for the tropics: Nakamura 1966, Nieuwolt 1966, Okoola 1980; for the polar regions: Benson & Bowling 1975);
2) heat islands tend to increase with city growth, as suggested proportional to the logarithm of the size of population (Oke 1973);
3) heat islands in industrialized areas are strongest on working days (mitchel 1962);
4) during hot spells, heat islands form areas of marked rise in mortality, especially amongst elderly people (Tout 1978).

The above observations lead to the identification of some causes of heat islands, which include:
1) increased absorption of solar radiation by built mass and hard surfaces (road beds and paved areas) in conjunction with black-tops, due to their excessive heat storage capacity;
2) lack of vegetation with its high potential of utilizing incoming energy for evapotranspiration, which leads to a cooling effect;
3) increased air pollution of different kinds, leading to additional heat absorption by the atmosphere.

The effect of these elements can be expressed in meteorological terms by the albedo, and in the building physics context by the sol-air temperature concept, where any radiative excess temperature is expressed by:

$I \cdot \alpha \cdot f^{-1}$, where I = incident radiation ($W \cdot m^{-2}$)
α = absorbance factor
f = surface conductance ($W \cdot m^{-2} \cdot {}^{o}K^{-1}$).

"f" is goverened by the convectional and evaporative characteristics of the particular material and its exposure.

Typical for an urban environment is that even after sunset the heat will heavily be stored and slowly re-radiated due to
1) the increased overall material-specific time lag;
2) repeated counter-radiation between adjacent walls and other hard surfaces.

Thus the air within the city will remain considerably warmer than the one in the surrounding countryside, where the above described reactions do not take place to such an extent. Furthermore, a dynamic exchange of the heated air masses is hampered by the increased friction between the lower air layers and the rough urban fabric. Thus the urban heat island effect is more clearly defined by the daily minimum temperature at night than by the maximum temperature at daytime.

This effect can be noticed at the higher latitudes in both winter and sommer season, even if the winter effect may be the result of somewhat different causes, since seasonal heating in line with the nocturnal low temperature inversion, linked with smoke, carbon dioxide and other pollutions, reduces the outgoing rediation (albedo), resulting in more elevated temperatures inside than outside the city.

In replacing the common urban fabric by more appropriate design elements, i.e. choice of materials and their specific application, the heat island can be effectively counteracted. This includes: 1) to re-establish a precipitation run-off with a time lag as long as possible by limiting the area of hard surfaces;
2) to use soft surfaces for planting suitable vegetation, thus providing ventilated shade and evapotranspiration for additional cooling;
3) to apply low heat capacity material in line with low sol-air temperature properties for the outer skin of the structural fabric;
4) to avoid black-top surfaces, which is related to above;
5) to prevent air pollution, responsible also for a wide range of specific health hazards and environmental damages.

Bearing such general rules in mind, the actual situation of Nairobi will be discussed now.

The most early investigation in the Nairobi urban climate has been conducted in 1965 (Nakamura 1966), when the population was close to 267000 (1962). A second investigation took place in 1978 (Okoola 1980), after the population increased by over three times to 835000 (1979). The 1965 study identified for the mean monthly minimum temperature a difference (ΔT) of $+1.3^{\circ}$K between the Jomo Kenyatta International Airport at Embakasi and Eastleigh - refer to table 1. This is rather small compared to the figures of large cities at higher latitudes, which range about 6-7°K in average to a maximum of 12°K (Oke 1973).

Table 1 - Nairobi Heat Island

Year	ΔT monthly mean min.temp.*	13-18 March ΔT mean min.temp.**		13-18 March ΔT mean max.temp.**	
1965	$+1.3^{\circ}$K betw.Embksi. & Eastleigh	—		—	
1978	—	$+1.0^{\circ}$K Gigiri / J.H.Sch.	$+1.1^{\circ}$K Embksi./ Eastl.	$+0.9^{\circ}$K Gigiri / J.H.Sch.	$+0.3^{\circ}$K Embksi./ Eastl.

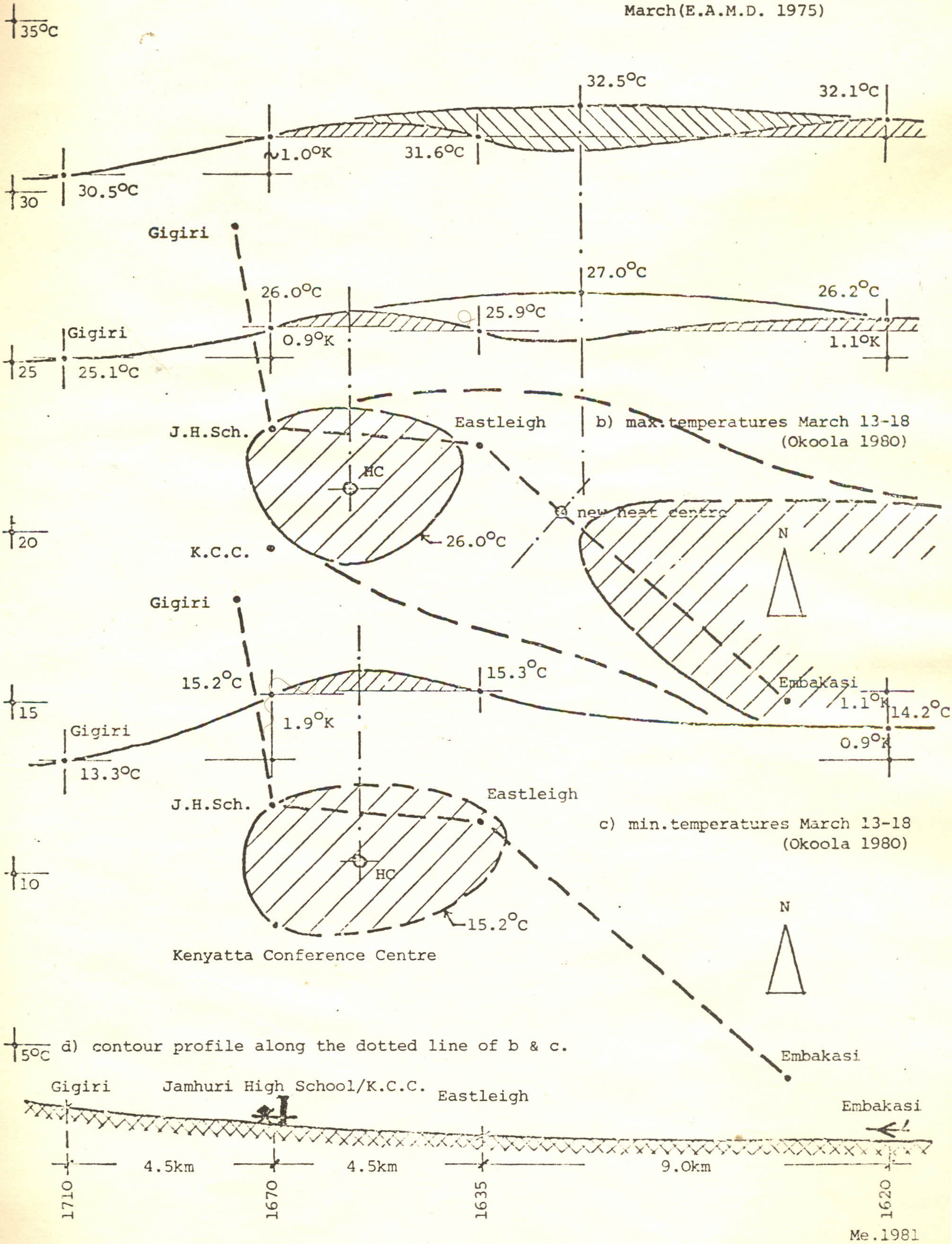
*Nakamura (1966) **Okoola (1980)

The 1978 investigation resulted in following observation:

For the period of 13-18 March - chosen for its favorable climatic conditions in building up a heat island, i.e. low velocity air movements and a cloudless sky during daytime - between Gigiri at the Northern outskirts of the town (UNEP-headquarters) and the Jamhuri High School at Parklands a thermal difference (ΔT) of $+1.9^{\circ}$K has been recorded for the mean min.temperatures; between Eastleigh and Embakasi a ΔT = 1.1°K, with almost identical temperatures at Parklands (15.2°C) and Eastleigh (15.3°C), including the Kenyatta Conference Centre in the South (15.2°C).

Thus the heat island can be identified as covering an elliptical area defined by the Jamhuri High School in the North-West, Eastleigh in the East, and the K.C.C. in the South-West with its centre around Starehe Boys Centre/Pumwani Maternity Hospital - refer to fig.1/c.

Fig.1 - Nairobi Heat Island/thermal profiles .... a) potential heat island on the basis of extreme readings for March(E.A.M.D. 1975)



For the mean maximum temperatures, following readings have been received for the same period:

Gigiri/Jamhuri High School ..... $\Delta T = +0.9^{\circ}K$

Eastleigh/Embakasi .... $\Delta T = +0.3^{\circ}K$,

which indicates that another heat centre has been built-up during the day in the vicinity of the city, whereas the former one maintains its extension and position as before - refer to fig.1/b.

As a result it can be stated that during the hot spell (Feb./ March) the minimum temperatures form a distinguishable heat island in Nairobi, extended over an area of 5.okm diameter in East-West, and 3.okm in North-South direction, with its centre around Starehe Boys Centre/Pumwani Maternity Hospital.

For the same period, the maximum temperatures show a heat island with an almost identical area and centre, but simultaneously another heat centre has been developed outside the city at the Embakasi plains, a savanna-like area with thermal properties during the dry season close to the ones of a paved surface.

The existence of the second heat island has to be considered as a concern for the future, since the "thermal valley" in-between might be filled up one day due to the city's expansion, creating an increased heat island with a new centre of an even higher temperature in East-Southern direction - refer to fig.1/a&b.

Present day planners should have this in mind when additional requisition of land has to be approved for the future growth of the city. The continuing conversion of open land into built-up urban areas will almost inevitably effect the thermal regime of the whole area, unless a most sensitive planning attitude, including climatic considerations, will be adhered to by all parties concerned.

In other words: the existing green areas/soft surfaces, which act as the "cool boxes" of the city - Arboretum, City Square, Jeevanjee Gardens, City Park, Uhuru Park, Karura Forest and others more - have to be maintained by all means. New ones have to be created in the land reserve, supposed to receive the future expansion. In the same way, the green suburbs have an important role to play.

Architects as well as engineers have to look for means to increase the overall albedo of the town, or in other words, to reduce the sol-air heat gain of the urban fabric, which mainly consists of solid mass (stone and concrete) and circulation surfaces (tarmac and paving). Sufficient soft surface areas have to be provided with an adequate provision of trees and shrubs for maintaining shade and ground moisture, which has to go hand in hand with a more conscious selection of building materials. Technical solutions are available. They have only to be implemented within acceptable cost limits.

Summarizing it can be said that for Nairobi the minimum temperature heat island is more distinct than the maximum temperature island (1.9°K - refer to fig.1/c). Both are at present still below the average values of most of the higher latitudes cities. The same can be said with regard to air pollution, at least as far as the vehicular traffic is concerned (Ng'ang'a 1980). But even then, future expansion of the city in South-Eastern direction, i.e. along the Mombasa Road, Enterprise Road, Outer Ring Road, should be dealt with extreme care in order to avoid adverse consequencies to the overall Nairobi climate.

A last remark should be added about the heat islands of other towns in Kenya. We saw already that the Nairobi heat island is still relatively small. Looking at two other kenyan towns like Mombasa and Lamu, heat islands do not seem to play an important role yet.

At Mombasa for example, the maximum temperatures do not develop a heat island, at least not as far as the available records allow to conclude (E.A.M.D. 1975). A positive thermal gradient between the two observation stations (Town Met.Station and Airport Met.Station) is restricted to 1.3°K for the minimum temperatures - refer to table 2.

Table 2 - Mombasa (E.A.M.D.1975)

March	highest extreme	lowest extreme
Airport Met.St.	37.3°C	20.8°C
Town Met.St.	35.3	22.1
ΔT	-2.0°K	+1.3°K

An investigation into the Lamu conditions (Meffert 1980) suggests a similar result: an essential difference between thermal readings at dofferent locations within the town area and at the Meteorological Station outside the town could not be identified for the maximum temperatures;
for the minimum temperatures a mean thermal gradient could be traced for January in the range of 1.1°K, for April/May nil, for July 0.8°K, for November 2.0°K - refer to table 3.

Table 3 - Lamu (Meffert 1980)

January	25/1		26/1		27/1		28/1		prevailing wind direction
	min.	max.	min.	max.	min.	max.	min.	max.	
Met.St.	24.3	31.2	25.0	32.0	25.6	31.7	25.6	31.1°C	
Town pos.	26.0	29.5	25.5	28.3	26.5	28.8	27.0	29.0	East
ΔT	+1.7	-1.7	+0.5	-3.7	+0.9	-2.9	+1.4	-2.1°K	
	mean min. ΔT = 1.1°K								
Apr.May	30/4		2/5		3/5		4/5		
	min.	max.	min.	max.	min.	max.	min.	max.	
Met.St.	27.0	30.1	25.1	26.7	26.6	28.5	26.6	31.4°C	
Town pos.	-	30.0	26.0	26.3	26.0	27.0	26.5	29.0	South
ΔT	-	-0.1	+0.9	-0.4	-0.6	-1.5	-0.1	-2.4°K	
	mean min. ΔT = 0.0°K								
July	27/7		28-29/7		30/7		31/7		
	min.	max.	min.	max.	min.	max.	min.	max.	
Met.St.	24.5	28.3	24.6	28.0	24.1	27.5	24.5	26.5°C	
Town pos.	25.0	27.0	25.3	28.0	25.5	26.0	25.0	26.0	South
ΔT	+0.5	-1.3	+0.7	-	+1.4	-1.5	+0.5	-0.5°K	
	mean min. ΔT = 0.8°K								
November	1/11		2/11		3/11		4/11		
	min.	max.	min.	max.	min.	max.	min.	max.	
Met.St.	24.6	29.4	25.1	30.5	23.8	30.0	25.2	30.6°C	
Town pos.	26.0	28.8	28.8	30.5	25.0	28.5	26.8	29.0	South-East/calms
ΔT	+1.4	-0.6	+3.7	-	+1.2	-1.5	+1.6	-1.6°K	
	mean min. ΔT = 2.0°K								

This can be considered as quite satisfactory, in particular for such a dense settlement as represented by Lamu with its extreme narrow walkways and flat solid roofs.

As main cause for such positive conditions, following aspects should be mentioned: 1) the limited extension of the actual solid town centre; 2) its favorable exposure to the incoming sea breeze most over the year, providing a maximum of dynamic through-ventilation; 3) the well suited traditional building material, i.e. coral stone and lime mortar, in conjunction with Makuti; 4) the rich provision of shading to the hard-surfaced narrow spaces left between the multi-storey buildings; 5) the intensively vegetated private gardens and tree-shaded public areas, like the market for instance.

This basic urban lay-out has to be considered es essential for the generally pleasant Lamu climate, even if one or the other actual house plan seems to be rather adverse to the prevailing warm-humid coastal conditions. Any conservation effort for this fine example of a Suaheli township should bear such details in mind.

From front cover:

G - Gigiri/UNEP
J - Jamhuri High School
KCC - Kenyatta Conference Centre
St - Starehe Boys Centre
P - Pumwani Maternity Hospital
Es - Eastleigh Airfield
Em - Embakasi Int. Airport

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The cover shows a section of map SK 58 Nairobi & Environs, scale 1:100 000, edition I.