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The performance of green roof with urban heat island

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Abstract

The temperature of metropolitan area continues to enhance because of the heat island incident. The practical high temperatures increase the energy problem of metropolitan area, deteriorate comfort conditions and amplify the pollution problems. To counter balance the observable facts, significant mitigation technologies have been developed and projected. Among them, the use of green roofs appears to be extremely promising, presenting comparatively high heat island mitigation prospective. Urban heat island has usually used the distinction plants index as the indicator of plants large quantity to approximation the land surface temperature plants relationship. This study examines the applicability of plants portion derivative from a spectral combination model as another marker of plants abundance.

Urban Heat Island has important impacts on the buildings energy utilization and outside ambient air quality .A variety of approaches, as well as observation and simulation techniques have been projected to understand the causes of urban Heat Island formation and to find the corresponding improvement strategies.

This paper presents an assessment of the techniques used to study urban Heat Island. The abilities and restrictions of each approach for the exploration of urban Heat Island improvement and forecast are discussed. The treatment of important parameters together with latent, sensible heat in addition to behavior of radiation, effect of vegetation and pool.

Keywords :- Urban Heat Island , Urbanization ,Water quality , Urban texture , Albedo, Transpiration , Evaporation

1. Introduction

The urban heat island is being gradually more visualized as a main crisis in many urban areas. There are various way to overcome these problem in which the performance of green roofs, multiply the advantages, beside the decrease of the roof surface temperature, it also get better the micro climate through the transpiration and evaporation process, delays and decreases the storm rain water runoffs, which numerous times is associated to city flooding, develops the visual feeling and keep away from the glare problem [19].

The climate of an urban area manipulates the kinds in which its outside areas are used. Particularly in the community areas proposed for utilize by such as parks, pedestrians, cyclists, squares, housing and shopping streets, will be used and enjoyed more regularly when they have a comfortable and healthy environment conditions. Due to an expected worldwide temperature get higher, the climate is probable to be additional uncomfortable particularly in summer, when an increase in heat stress is estimated [18].

The urban heat island depends from the volume of the urban area and the climate circumstances like the cloud cover and clear sky condition. Additional characteristics, like a need of ventilation, the heat release of motors, cars .The elevated absorption feature of the majority streets, pavements combined with a be short of shadow spending from vegetation, can appreciably add to urban heat islands [Laar et al., 2002][19]. The studies of urban climate have long been connected about the amount of the difference in experimental ambient wind temperature between urban areas and their nearby rural areas, which together illustrate the urban heat island effect [17].

The enlargement of world urbanization has been comprehensively accelerated since the Second World War. According to the Population Reference Bureau 50 % of the earth population is settled in urban areas. Also, it is estimated that inhabitation in urban area will reach 60 % by 2030. Due to huge building construction is in progress to respond to this very high dwelling demand. This extreme and unplanned development of urbanization has caused undesired side effects around the earth. Urban Heat Island (UHI) as an outcome of urbanization was first recognized by Howard in 1818[1]. In summer seasons UHI significantly decreases the outside air quality as well as increasing the energy require of a city, and as a result of this energy demand increase, At large scale power outage may occur due to the increase of the air conditioning system procedure. Thousands of deaths are yearly reported due to the heat connected illnesses [1].

Elevated city temperatures enlarge the energy expenditure for cooling and increase the electricity demand [Santamouris et al. 2001]. Heat island in the urban area Greece, twice the cooling load of buildings become almost triples their electricity requirement. The cooling energy amplify is accompanied by intensification of greenhouse gasses patterns in cities and enlarge of ozone concentrations [15]. While the environmental footprint of the cities is amplified [Santamouris et al., 2007], the outside thermal comfort situation get worse [Pantavou et al., 2011], the thermal pressure in low income dwellings is enlarged, the inside thermal comfort levels are dangerously decreased and health troubles are increased [15].

Enlarge of the green roofs in urban area, contribute to reduce the urban surface and temperatures a heat island effect. Research studies reported by Gill et al. (2007), demonstrate that an amplify by 10% of the urban green roof in Manchester could repay the estimated increase by 4 K [15]. There are two major categories of green roofs, Extensive roofs which are light weight and are covered by a slim layer of plants and intensive roofs which are heavier in weight and can support trees. Green roofs present a various types of advantages like storm rain water runoff management, increased roof permanence, reduce energy expenditure, improve air quality and noise reduction, offer space for urban flora and fauna and reduce of urban heat island [Mentens et al., 2006]. Green roofs may exhibit considerably to decrease heating and cooling electric loads.

The performance of reproduction urban texture in terms of combination of short wave and long wave radiation, transpiration, releasing of anthropogenic high temperature. The most successful approach to reduce UHI include increasing material's albedo in a city, increasing vegetation, ponds inside urban areas, sinking released of anthropogenic heat inside of building[1].

2. The causes of urban heat island

[1] Absorption of short wave solar radiation in low albedo surface and by numerous reflections among buildings and road surface.
[2] Air pollution in the urban area
[3] Hindrance of the sky by buildings consequences in a reduced solar long wave radiative heat loss from street. The heat is captured by the barricading surfaces, and absorbed and back to the urban space.
[4] Heat discharged by ignition practices, such as industries, space heating and traffic.
[5] Enhance the heat storage by building materials with large scale. In addition, cities have a bigger surface area compared to rural areas, consequently additional heat can be stored.
[6] The evaporation from city areas is reduced because of less amount of plants compared to rural areas. As a result, additional energy is put into convection heat and less amount of latent heat.
[7] The disordered heat transfer from within roads is reduced by a reduction of air velocity.

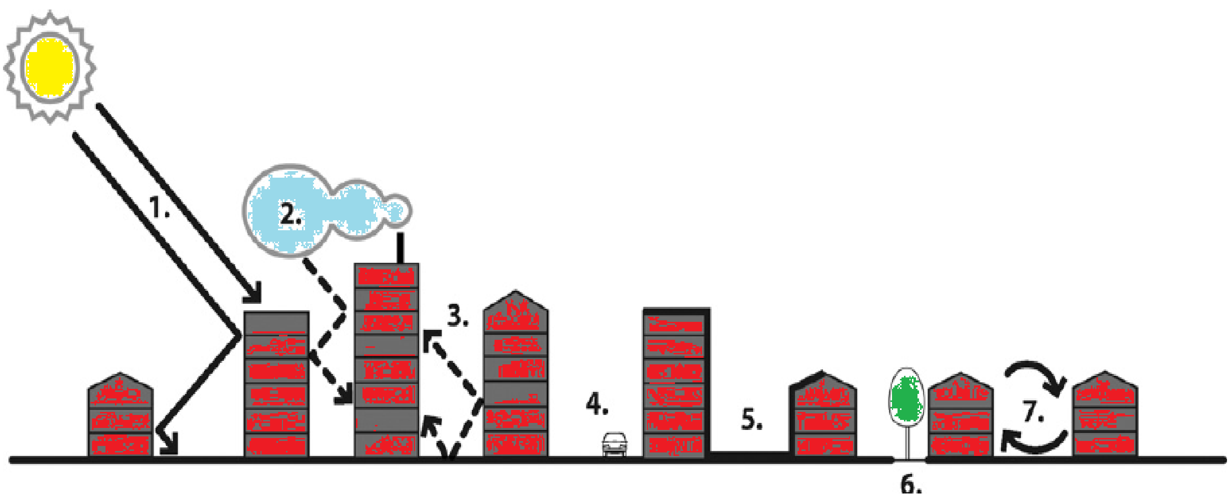

Figure-1 :- Reasons urban heat islands.

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3. Health consequences of warm stress

The human body has a definite temperature system of a range of mechanisms to deal with a difference between heat gains and losses. These systems include to regulate the flow of blood to the membrane, shaking and muscle tensioning to create heat, sweating to drop heat, modifies in respiratory time and heart rate, and the construction of hormones. The excessive temperatures can place major stresses on the thermoregulatory structure, with uneasiness or as a consequence of health risk. Heat stress can reasons for illnesses such as syncope, reasoned by a breakdown of the movement to sustain blood pressure and provide oxygen to the brain, heard stress and heat stroke. A heat stroke can show the way to respiratory syndrome, kidney failure, liver failure and blood clots [Hoyois et al., 2007][18].

4. Tools for to reduce urban heat island

4.1 Vegetation

Plants cool the surroundings dynamically by transpiration, evaporation and passively by shading exteriors that would have absorbed solar short wave emission. Plants has an average cooling result of 1 ^{0}C - 4.7 ^{0}C that extends 100 m - 1000 m into an city area, but it is extremely dependent on the quantity of water available in the plant [Schmidt et al., 2006][18].

4.2 Water

Water can cool nearby by evaporation process, by absorbing warmth when there is a huge amount of water mass which play the role of heat buffer. Water has a typical cooling effect of 1 ^{0}C - 3 ^{0}C to a level of about 30 m - 35 m. Functions of water in general are more useful when they have a huge surface, or when the water is flowing from a fountain. The result of cooling by water evaporation depends on the airflow [18].

4.3 Effect of trees and ponds

Vegetation appreciably affects the surroundings energy balance by transpiration from leaves, evaporation from water from soil, by shading of the solar energy radiation and by reducing the velocity of wind. This denotes, the effect of vegetation is as important tool to reduce the UHI [12]. Water ponds can changes the energy budget of building volume. Comparing to solid surfaces, these elements have various physical and thermal properties. Therefore, they can accumulate the high temperature inside or discharge the latent heat radiation through the hard surface of city [13].

4.4 Built form

Building geometry and compactness are the variables that manipulate the incidence of radiation on materials that can accumulate heat, and the trapping of heat by numerous reflections between street surface and buildings. Hindrance of the sky by buildings consequences as a decreased long wave radiative heat loss from street. In excess of heating by solar heat radiation in summer can be decreased with more ratios of street height to street width [Futcher,et al., 2008]. Nevertheless this can also decrease wind flow, help numerous solar reflections and lower the sky view factor. Better choices to shade buildings are trees, green roof and green walls, which are green in summer season and transparent in winter season. It moreover acts as a shading device which can be used in summer [17]. Building form also decreases air velocity. Designing through wind can guide to efficient cooling of buildings and city areas. Stimulating air for ventilation in summer can show the way to a extremely uncomfortable or even hazardous situation in winter season. The orientation of streets will consequently bring some design challenges, particularly taking into account together solar and air orientation [Esch et al. 2007][18].

A different approach to get better ventilation is to produce a mix of the wind in the covering layer with the wind from the periphery layer. The best ventilation is obtained at a height to width ratio of approximately 0.5. At a height to width ratio of extra than 2 there is almost no mix of the canopy and periphery layer [Xiaomin et al., 2006][18].

4.5 Material

The thermal access of materials too plays an important function. Materials similar to store brick more heat and spread out that warmth into the wind throughout night time. Hollow block concrete has a lesser thermal access and consequently stores less heat. The temperature dissimilarity among materials can be very huge. Throughout heat waves the temperature in cities can collect day by day when there is no cooling air.

5.0 Approach to study the urban heat island

5.1 Observational approaches

In current years, several common interpretations have been made in accordance to the topographic scope used in heat island studies. Arnfield et al., (2003) summarize them as follows, UHI concentration decrease with rising wind velocity, UHI intensity decreases with increasing cloud envelop, UHI intensity is more harsh throughout the summer, UHI intensity tends to increase with increasing city dimension and inhabitants. The greatest UHI intensities were found for sunny days under clear and calm circumstance [2].

5.2 Field measurement

In the field analyses approach, the close to surface temperature pattern in urban area is commonly compared with rural region. That involves the investigation of statistics on urban rural differences based on pairs of permanent or movable stations [3]. Field measurement method was originally used to study UHI by Howard in 1818 for the metropolitan city of London. Since then, numerous monitoring investigations have been reported in different cities [4].

In spite of that, one should note that field measurement, as an autonomous way, has several restrictions. The expansion and fitting of measurement devices around a town are usually very costly and time consuming job. In addition, restricted stationary network or mobile stations is usually used, and only a restricted number of parameters are concurrently measured. This implies that it is not probable to exhibit all the three dimensional spatial allocation of the quantities within a metropolitan area. In addition several investigations used measured data for the confirmation of mathematical models or boundary condition settings in simulation schemes [5]. Nunez and Oke [6] calculated the radiation fluxes, wind velocity and temperature which were later on used in an urban model.

5.3 Thermal remote sensing

Through the improvement of sensor technology, thermal remote examination of UHI became achievable through the use of satellite. The resultant exterior temperature contains the effects of exterior radiative and thermodynamic properties, together with exterior moisture, surface emissivity, surface albedo, the irradiative contribution at the exterior, and the effects of the near exterior ambiance [7].

It should be noted that remote sensing is an extremely costly approach, and it is not achievable to have steady images from the urban area. This is partially associated to the capability of the used equipments and partly due to the atmospheric connections. This means that experimental outside surface temperature can be extensively different from the ambient air temperature inside street [1].

5.4 Small-scale modeling

In this technique, the urban area is typically replaced with prototype on obeying the parallel presumption between actual case and small scale model [8]. The prototype models are approved either using air tunnels or outside spaces [9]. It is hard and sometimes unachievable to ensure similarity between the actual case and the prototype in outside spaces. For example implementing solar radiation comparison is complicated in air tunnel modeling. Small scale modeling is generally used in UHI studies to validate and to develop the mathematical models.

Small scale modeling can facilitate to investigate the impact of limited amount of parameters of a building on its surroundings (for example dimension, contamination distribution) or over the small area of a city [10].Although it is not simple to model complex dynamics of environmental interactions in this approach that can be compensated by selecting suitable periphery circumstances [8]. The earthly and structural investigation of the UHI under alteration of various parameters cannot be handled by this technique.

5.5 Simulation approaches

Alongside with the inspection approaches, mathematical models have been developed to explain city climate problems together with UHI. Nevertheless due to the complication of UHI, main simplifications are commonly required. However the computational techniques have advanced broadly allowed the investigators to explain mathematical models for large scale problems. Along with these models energy balance and dynamical numerical methods displayed the almost dependable and suitable outcomes [1].

5.6 Energy balance model

The energy balance for a building was first suggested by Oke [11]. This process uses the law of conservation energy for a given volume.

- $R_n = Q_E + Q_{sensible} + Q_{conduction}$
- Where
- Q_E = Evaporation heat loss in soil
- $Q_{sensible}$ = Sensible heat (convection heat)
- $Q_{conduction}$ = Conduction heat transfer

Lack of wind velocity field serves as the main limitation of the energy balance models the velocity field information is essential in order to study the consequence of flow pattern to study formation of the atmospheric phenomena and to establish the sensible and latent heat fluxes. Providing record for three dimensional geometry of building canopies and urban structures in a town is extremely costly in terms of time and computer load. So the town is typically replaced with homogeneous columns of analogous buildings [10].

5.7 Computational fluid dynamics

In energy balance models in which velocity and temperature fields are divided, Computational fluid dynamics all together solves all the main equations of fluid inside the urban areas, temperature, water vapor and chemical response. As an outcome, computational fluid dynamics is able of obtaining additional correct information on UHI allocation inside and above the building canopies. Computational fluid dynamics simulations are typically divided into diverse scales. Two scales are commonly used in UHI study meso scale and micro scale.

5.8 Meso scale model

Meso scale models are lesser than synoptic scale and bigger than micro scale system. The straight resolution of these models is about ranged from1 KM to 700 KM. Also, these models perpendicularly vary with depth of planetary boundary layer among 200 m and 2 km. In meso scale models large scale communications under the planetary boundary layer are resolved.

5.8 Micro scale model

The meso scale model, micro scales determine the conservation energy equation within the surface layer. Meaning that the straight spatial quantities are assumed with bulk values in meso scale model, wherever those are simulated with real geometry and details with surface layer interactions in micro scale model.

5.9 Radiation model

The solar radiation fluxes on the development of UHI are really important and the numerous models have been developed to explain the radiation exchange method inside urban areas. The surface solar energy balance model, equation is a appropriate practice for modeling. The net radiation balance to surfaces within a urban area is generally can be simplify as follows

- $I = K_i + K_r + L_i + L_r$

Whereas-

- K_i = Incident short wave radiation
- K_r = Reflected short wave radiation
- L_i = Incident long wave radiation
- L_r = Reflected long wave radiation

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5.10 Short wave radiation model

Solar radiation adds considerably to daily heat island when the sky is typically clear. Solar radiation is in part absorbed by metropolitan area, and partially reflected. The incident solar energy radiation on urban area is also composed of direct and diffuse fractions. Estimation of the direct and diffuse portions of radiation is a function of cloud cover which is not actually simple to find. Numerous models have been developed to estimate the cloud cover [7]. Another important issue in short-wave radiation models is how to trace the reflected portion of direct and diffuse parts of solar radiation [1].

5.11 Long-wave radiation model

Long-wave radiation is additional dominant in the development of night-time UHI. In that matter, hot surfaces of the town cannot correctly produce radiation to the sky. That is due to the existence of cloud in the sky seen by buildings. As a result, it is essential to develop a model that find out the long wave radiation from every surface to the sky [1].

6.0 Tools for urban design the strategies and performance

6.1 Increase the albedo in the city

It is recognized that large scale change of albedo has a serious impact on the neighboring maximum ambient temperature. A number of studies have been conducted to examine the impact of diverse albedo related mitigation techniques on the potential decrease of ambient temperature. It is well recognized that there is a negative relationship between albedo effect and surface temperature. The larger albedo the lesser the surface temperature [14].Gaffin et al., (2006) investigated that an albedo of green roofs 0.7–0.85. It is specified that the subsurface temperature was considerably lesser than the green roof surface temperature. That demonstrates that green roofs can decrease the thermal loading. Surface temperature was mostly associated to solar energy reflectivity. Solar energy reflectivity is prejudiced by plants richness, where larger biomass led to larger solar energy reflectivity [Lundholm et al., 2010].

6.2 Potential of green roofs

Due to fast urban enlargement in developing countries urban heat islands are growing very speedy. Green roofs can diminish these concerns. The albedo of green roofs range 0.7 to 0.85 is higher than the albedo range 0.1 to 0.2 of tar bitumen and gravel roof [15].The estimate temperature increase of 4 ^{0}C atmospheric temperature in next 80 years in Manchester city these crisis can be resolved using 10% of green roofs [Gill et al., 2007].The adjacent temperature can be reduce up to 0.3 ^{0}C to 3.0 ^{0}C after applying the green roofs at huge scale. The performance of Green roofs are very efficient in hot and dry climatic conditions [15].Smith and Reober et al. ,(2011) investigated the impact of green roofs in urban heat island the ambient temperature decrease up to 3^{0}C in Chicago, ambient temperature reduce .37 ^{0}C to.86^{0}C at the height of two meter [Savio et al .,2006] , the solar radiation intensity diminish from 900 w/m^{2} to 300-400 w/m^{2} [Takebay Moriyama et al.,2007].

Table -1:- Characteristics of the existing studies

References	Type of green roofs	Investigation
Smith and Roeber et al ., 2011	Extensive green roof	Urban temperatures were 2–3 K cooler
Savio et al., 2006	Extensive green roof	temperatures at 2 meter height reduce 0.37–0.86 K,
Chen et al. ,2009	Extensive green roof	Almost negligible impact because of the high of the buildings
Ng et al. ,2012	Extensive green roof	Almost negligible impact because of the high of the buildings

Savio et al. (2006) investigated that impact of green roofs on the potential ambient temperature diminish at two meter height above ground, has been measured for New York city. After applying the green roofs it was measured that the average temperature reduces in the different parts of the part of the city between 0.18 K and 0.36 K. In similar case the normal 3.00 PM decrease of highest temperature ranged between 0.31 K and 0.62 K of the measured areas [16]. Together extensive and intensive green roofs were simulated. It is establish that the probable diminish of the ambient temperature at road level in this sky-scraping and rise high density area is approximately zero. The research concludes that when the building elevation to street width ratio exceeds one, the feasible cooling benefits at mark are low [Ali Toudert and Mayer et al., 2007][16].

The most excellent result to get better the urban micro climate in existing city area with high density is enhance of green areas, developing the shadowing and enlarging the evaporation rate. As a result cooling attempts by evaporation have a vast potential. In various cases it may be possible to execute new green area. In addition increase of plants all along the streets might be a opportunity to develop the micro climate [19].

Table 2:- Latent heat by green roofs

References	Green roofs	Solar radiation intensity w/m^2)	Latent Heat w/m^2)
Hodo Abalo et al., 2012	Leaf area index =2	520	250
Hodo Abalo et al., 2012	Leaf area index =3	520	300
Hodo Abalo et al., 2012	Leaf area index =4	520	350
Hodo Abalo et al., 2012	Leaf area index =5	520	450
Hodo Abalo et al., 2012	Leaf area index =6	520	500
Hodo Abalo et al., 2012	Leaf area index =7	520	560
Feng et al. (2010)	Leaf area index =4.6	900	600

7.0 Climatologically variables

Solar radiation strength mainly decides the solar heat storage and outside temperature of the roofs as well as the quantity of the solar heat transmitted to the building and the transpiration, evaporation. The solar heat characteristics of the incoming solar radiation are also significant in green roofs surface where the color, moisture and the association of the layers vary the transmittance, reflectance and absorption [16].

Air velocity and atmospheric disorder describe the heat transfer coefficient between the exterior and the atmosphere and decide convection heat flux. Higher air velocity enhances the flux of convection heat and evapotranspiration from the green roofs [16]. Higher air velocity increases the transfer of water vapor from the soil, contribute to enhance the speed of evapotranspiration (Tsang and Jim, 2011). As considered in Tabares Velasco and Srebric, (2011), when the air velocity enlarges from .1 m/s to 1 m/s, evapotranspiration rate in the green roof enlarges by 10% to 30% [17].

The thermal accommodation of the roofs and their U value are significant thermal factors describing their achievements. Amplified the thermal ability of the roofs leads to a maximization of the stored solar heat decreasing peak surface temperatures [16]. The consequence of soil deepness of the green roofs and the analogous U value of the roof establish to be very significant concerning the energy expenditure of the buildings [Sailor et al., 2012]. Predictable U values of green roofs with a shallow soil, varies among 1.17 and 2.70 $W/m^2/K$ [Tabares Velasco and Srebric, 2009]

Sailor et al., (2012) investigated that amount of evapotranspiration from a green roof has concluded that the Leaf Area Index is the main factor for evaporation losses. It is recognized that in evapotranspiration process losses for the duration of the peak period ranges between 250 and 550 W/m^2 for Leaf Area Index of 2 and 7, respectively[16].

Table -3:- Heat reduction in green roofs

References	Heat flux reducing
Lazzarin et al. 2005	60 %
Onmura et al. 2001	50 %
Tang and Jiang et al. 2009	73 %

8.0 Change the albedo from a worldwide perception

A number of studies have conducted the problem of the urban area albedo change from a worldwide. In Akbari and Matthews (2010), it was considered that enlarge of roof and asphalt road by 0.25 and 0.15 correspondingly could reduce radiative forcing by 0.15 W/m^2 over the worldwide urban land area. The study described in Menon et al. (2010), it was investigated that when the albedo of roofs and pavements enhance by 0.25 and 0.15 respectively, the possible CO2 offset is close to 57 Gt [14]. It is investigated that the mean sun radiation require per 0.01 increase of albedo is -1.38 W/m2. This may consequence in removing 1.76 million tons of carbon dioxide emissions.

Conclusion

In the green roofs the vegetation creates huge the shielding effects on the roof. The albedo to solar heat energy of reflective roofs is an important variable explaining its thermal budget. Elevated albedo reduce the absorb range and the gathering of solar heat in the roof and reduce its surface temperature which communicates to lower convective heat fluxes and higher mitigation prospective. The typical ranges of emissivity for a green roof belong from 0.9 to 0.95 depending on vegetation variety. Vegetation absorbs solar radiation to increase biological photosynthesis to reduce absorption of the solar energy by the top soil and the roof structure. It investigated that the average absorbed solar energy by the green roofs is close to 23%. The efficient albedo of green roofs is extremely achieved by the density of the green area on it.

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