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DEVELOPMENT OF THE METHODS FOR CALCULATING THE MAIN INDICATORS OF HEAT ISLANDS IN URBAN AREAS

Abstract. The article is dedicated to the methods developed to calculate the main parameters of “heat islands” that appear in densely built-up urban areas. Although remote sensing imaging is ideally used to track and detect frequent land cover changes in urban and surrounding areas as a result of sustainable urbanization and to calculate key parameters of “heat islands” seen in densely populated urban areas, satellite imagery is digitally manually. The transformation of a parametric image into a land cover map using existing methods of classification is a long process, and therefore methods are proposed to determine the main indicators of the impact of “heat islands” in urban areas. A modified building density index has been formulated, which is highly informative, involving: (a) the proposed index reaches an extremum when the known building density index BDI and NDVI are equalized, (b) when the specified maximum is reached, it is easy to calculate the LST indicator using the known regression dependences of BDI and NDVI from LST. The method has been developed to calculate the area of “heat islands” on the base of the equivalent radius calculation using the known dependence function of the building density on the distance to the center of the urban area. Our study shows that the distribution of buildings and the slope of the relief affect the surface temperature (LST), in addition, the ratios of different LSTs vary in cities of different sizes, and each city has a temperature difference in LSTs, so the urban heating island To reduce the impact, it is important to identify the characteristics of the thermal environment in cities of different sizes. Urban greening is increasingly valued by cities around the world as an effective measure to reduce the negative effects of the urban heating islands, with different numbers and types of landscape dimensions, different statistical methods used in different surveys, as well as metric scale dependence and contextual differences between cities and we can overcome these challenges by conducting comparative research on time and space using a consistent methodology.

Keywords: heat islands; urban area; surface temperature; informativeness; method.

Introduction

As the results of numerous studies show, “heat islands”, i.e., areas with higher temperatures appear not only in the cities of developed countries but also in developing countries. The main reasons for the change in the temperature of the earth's surface in urban areas are the lack of vegetation, thermal and physical properties of construction materials, the presence of buildings, uneven surfaces, and the presence of anthropogenic heat sources. All these factors lead to a change in local energy and an increase in atmospheric temperature in densely built-up areas of cities [1-5].

Over the years, land use and land cover changes have different environmental impacts, and urbanization, i.e., the conversion of natural surfaces into the population and economic growth uses, has a major impact on the urban climate, and area measurements and numerical simulations show that changes in surface features and vegetation occur in urban areas has a significant impact on local climate change near the surface [10].

Land cover in urban areas tends to change more rapidly in a short period of time than elsewhere due to sustainable urbanization, and urbanization, especially in urban and suburban areas, causes frequent changes in land cover as a result of rapid economic development. are found because they are relatively modern and give a panoramic view [8].

Dry surface temperature (LST) measured from satellite imagery has been used to study local and global climate models, urban islands, and the use of remote sensing in groundwater or surface temperature studies has increased because it provides a synoptic and wide view of an area. Numerous studies have been conducted using LST and NDVI to determine the relationship between urban surfaces and heating temperature from images [9].

Analysis of publications. According to the work [1-6], a fairly strong correlation between surface temperature (LST) was revealed and building density in urban areas, where the correlation coefficient reached 0.61. As mentioned in [7], such thermal anomalies in urban areas, together with the general trend of climate change towards warming, lead to the effect of global warming in cities, which negatively affects the health and working capacity of the urban population, increases mortality, and shortens life expectancy. According to the estimates presented in [7], during 1983-2016s, globally, the thermal impact on the urban population increased by almost 200%, at the same time, the growth rate of such impacts outpaced the increase in the urban population by 52%. The above-mentioned issue emphasizes the importance and relevance of the development of new methods and techniques to assess the physical and spatial indicators of the “heat islands” effect. Furthermore, the article illustrates the proposed methods for determining the main physical and geometric indicators of urban areas with higher temperatures.

Research results

In order to assess the rate of “heat islands” effect, there are various spectral indices, the main of which are the following building density indices: the normalized building density index of NDBI, defined as:
As it is seen from (1), the normalized building density index is defined as the difference between surface reflectance in the mid-infrared (MIR) and near-infrared (NIR) areas. NDBI was first proposed in [8] and is a dimensionless estimate of building density in the area where high values of this index indicate a high degree of building. The newly introduced MBBDI index under condition (10) reaches a maximum, which prevents the density of urban land use can be expressed as a function depending on the distance to the city center as a modified sigmoid function:

\[ f(r) = \frac{1-c}{1+\exp\left[\frac{r-c}{D}\right]} + c , \]  

where \( f \) is an urban density development; \( r \) is the distance from city center; \( c \) is a constant as an asymptote; \( f \) determines the density of buildings on the outskirts; \( D \) is a constant characterizing the degree of city expansion.

Note that for compiling temperature maps, such a concept as normalized surface temperature, i.e., \( LST_n \) is often used, defined as

\[
LST_n = \frac{LST - LST_{min}}{LST_{max} - LST_{min}},
\]  

where \( LST \) is current temperature; \( LST_{max} \), \( LST_{min} \) are respectively, the maximum and minimum temperature values in the area. The results of the analysis of the regression relationship between \( LST_n \) and indicators of \( f(r) \), carried out according to the method of concentric rings, the center of which coincides with the center of the urban area (Fig. 2), are presented in [10]. The perimeter of each of the rings, indicators of \( f(r) \) and \( LST_n \) and regression functions were calculated.

\[
LST_n = LST_n(f(r)).
\]
1. Measurement of LST in each pixel of the study area.
2. Calculating $LST_n$ on all pixels.
3. Determining $f(r)$ on all pixels using the regression curves shown in Fig. 3.
4. Averaging values $f(r)$ on all pixels.
   \[ f(r)_{av} = \frac{\sum_{i=1}^{N} f(r)_i}{N}, \]  
where $N$ is the number of pixels;
5. Using the inverse transformation of the formula (15) in the form
   \[ r = \phi(f(r), D, c) \]  
substituting $f(r) = f(r)_{av}$, with known $D, c$ the value $r_{eq}$ equivalent radius is calculated.
6. The average area of “heat islands” is calculated according to the formula $S_{h.i.}$
   \[ S_{h.i.} = \pi r_{eq}^2. \]  
Thus, formulas (15)-(20) form the basis of the proposed method for calculating the area of “heat islands” in urban areas.

**Conclusions**

Thus, the article proposes methods for determining the key indicators of the effect of “heat islands” arising in urban areas.

A modified building density index is proposed, which is highly informative, including the followings:

a) the proposed index reaches an extremum when the known building density index of $BDI$ and $NDVI$ are equalized;

b) when the specified maximum is reached, it is easy to calculate the indicator of $LST$ using known regression dependencies of $BDI$ and $NDVI$ from $LST$.

The method for calculating the area of “heat islands” is also proposed, based on the calculation of the equivalent radius using the known dependence function of the building density on the distance to the center of the urban area.

**References**

Проробка методики розрахунку основних показників островів тепла в місці
Бекірова Лала, Мамедова Есміра, Бунятова Ельвіра

Анотація. Стаття присвячена розробленому методику розрахунку основних параметрів «острівців тепла», які виникають у густонаселених міських територіях. Хоча зображення дистанційного зондування ідеально використовується для відстеження та виявлення частіх змін ґрунтового покриву в містах та прилеглих районах, у результаті сталої урбанізації та для розрахунку ключових параметрів «острівців тепла», які спостерігаються в густонаселених міських районах, супутникові зображення використовуються в цифровому вигляді. Внесення параметричного зображення в карту земного покриву з використанням існуючих методів класифікації є тривалим процесом, тому запропоновано методи визначення основних показників впливу «острівців тепла» в міських районах. Сформульовано модифікований індекс щільності забудови, який є високоінформативним, що включає таке: (a) запропонований індекс досить екстремну, коли відомі індекси щільності забудови BDI та NDVI відрізняються, (b) коли досягається заданий максимум, це надає можливість легко розрахувати показник LST, отримувати відомі розрахунки величини BDI та NDVI від LST. Розроблено метод розрахунку площі «острівців тепла» на основі розрахунку еквівалентного радіуса з використанням відомих регресійних відносин BDI та NDVI від LST. Розроблений метод розрахунку площі «острівців тепла» на основі розрахунку еквівалентного радіуса з використанням відомих регресійних відносин BDI та NDVI від LST. Розроблено метод розрахунку площі «острівців тепла» на основі розрахунку еквівалентного радіуса з використанням відомих регресійних відносин BDI та NDVI від LST.

Ключові слова: острові тепла; міська територія; температура поверхні; інформативність; метод.