Adaptation to Climate Change:

Urban Green Areas as Cooling Safeguards

Kyiv 2016

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Authors are also sincerely thankful for technical assistance in fieldwork, discussion and selection of materials, to:

Fevzi Ametov, Co-Founder at Drone.UA;

Oleksandr Polischuk, PhD in Biology, Post-Doctorate Student at the M.G. Kholodniy Botanical Institute, National Academy of Sciences of Ukraine;

Initiative group of students of the 2nd and 3rd years of study, Department of Environment, National University "Kyiv Mohyla Academy": Darya Bugaychuk, Anna Voitovych, Anastasia Pastushenko, Anastasia Starenka, Maksym Semak, Ksenia Potyomkina.

We also thank for comprehensive support of our work throughout the whole period of the project to **Nadiya Artmyeva**, Project Coordinator at the National Ecological Centre of Ukraine, and **Nataliya Gozak**, WWF Project Coordinator in Ukraine.

Editor: **Oleksandra Khalaim**

Design and layout: **Mila Grabar**, illustrator and graphic designer.

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Published by Ukrainian Environmental Club Green Wave as part of the project "Urban Green Areas as an Element of Adaptation to Climate Change" funded by the National Ecological Centre of Ukraine (NECU) under the Climate Forum East II (CFE II) Programme. This Programme is funded by the European Union, Austrian Development Agency, and Austrian Red Cross.

Contents

Introduction

This brochure contains a summary of research conducted under the project "Urban Green Areas as an Element of Adaptation to Climate Change" aimed to increase the adaptive capacity of urban green areas in big cities of Ukraine in order to address climate change. This research suggests more efficient measures for management and planning of urban green areas, which will improve their resilience to droughts and increased temperatures. On the other hand, the project outcomes will contribute to a better efficiency of green areas in terms of adaptation of urban population to extreme temperatures, increased concentrations of CO_2, and direct sunlight.

In course of the project, the working group was investigating how main tree species in the city of Kyiv were functioning during the heat waves of 2016, and analyzing the legislative framework applicable to management of urban green areas, including in terms of how it addresses the problem of climate change.

The research covered:

1. Physiological activity of park tree species in stressful weather conditions (hot weather).

2. Finding actual size of green areas in residential districts of the city of Kyiv through analysis of satellite imagery.

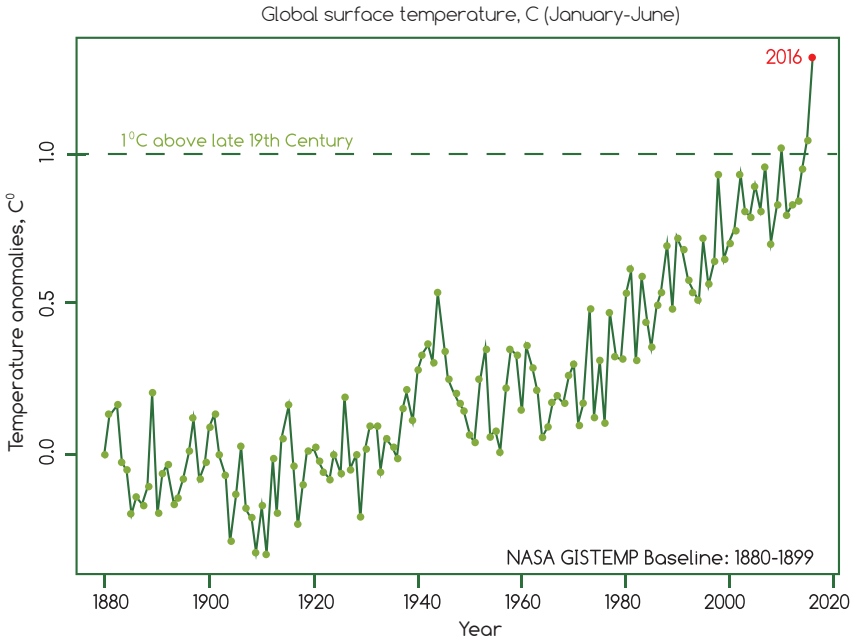
3. Impact of various types, density and sizes of green areas on local microclimate using an unmanned aerial vehicle (UAV) for thermal imaging.

The project has delivered experimental data on the efficiency of various types of plants for formation of urban microclimate. Data analysis was used as a basis to prepare recommendations for utilities enterprises responsible for urban greening and municipal administrations on how to address the climate change problems in planning of new areas and managing the existing ones, and recommendations on how to amend or supplement the existing laws and regulations governing urban greening.

Global warming:
temperature implications of climate change in cities

Weather observations both in Ukraine and abroad demonstrate the tendency to a warmer Earth: significant temperature increase and reduced precipitation in summer months is expected in the upcoming century, which will lead to the increase of hot and dry patterns (Jylha et al. 2008, Shevchenko et al. 2014, Gorny et al. 2016).

On July 19 this year the National Aeronautics and Space Agency (NASA) reported that the six-month period from January to June 2016 was the planet's warmest half-year on record, with an average temperature 1.3 degrees Celsius warmer than the late nineteenth century (NASA's official web page, Patrick Lynch).



Consequences of global warming will be more explicit in big cities due to limited air ventilation, larger areas covered by heat absorbing structures (such as buildings and asphalt roads), and smaller green spaces. This poses life and health of urban population at risk. Extreme temperatures cause additional stress for cardiovascular system and airways, and contribute to the development of infectious diseases. According to the WHO, 155,000

deaths annually (or 19% of the overall mortality) are caused by preventable environmental impact.

Climate change, specifically temperature change in cities, is expressed as heatwaves (in time scale) and heat islands (in spatial scale). According to the World Meteorological Organization, a heatwave (HW) is when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5 ˚C, the normal period being 1961-1990. An urban heat island (UHI) is a city or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities (Howard, 1818).

According to the Scientific Centre for Aerospace Research of the Earth (CASRE), Institute of Geological Sciences, National Academy of Sciences of Ukraine, from 2003 to 2011 the surface temperature in certain districts of Kyiv raised by 7–10˚C (Stankevich, Filipovich, 2013). Monitoring of the thermal field in the city of Kyiv over the period from 1984 to 2014 showed that the size of green areas and density of urban zones both have a significant impact on the formation and characteristics of heat field in the urban territories. Parks and forests tend to have minimal surface temperature due to natural evaporation and absence of man-made surfaces, while abnormally high surface temperature is observed above big road intersections, major avenues and highways (Filipovych, Krylova, 2014).

While researching thermal fields of Kyiv, experts of the Scientific Centre for Aerospace Research of the Earth (CASRE) have concluded that small size of green areas and density of urban zones cause local distortion of microclimatic conditions and thus contribute to climate change on the regional level.

Urban green areas during summer heatwaves

How is in the West? Overview of the most typical studies on urban heatwaves

In Europe, the standard of green areas is 20 m2 per capita (Lesnik and Girs, 2015). Since the 1970s, researchers have been trying to identify how comfort and safety of inhabitants of big cities depend on planning of green areas as of an element of adaptation to climate change and to extremely high temperatures. We have tried to analyze the most typical studies on this issue:

Table 1. Brief overview of studies on connection between microclimatic conditions of urban green areas and human comfort

#	Country, city, year	Objective	Methodology	Sampling
1	USA, Syracuse, NY 1977	Measurements of the physical environment of urban open spaces were used to compute thermal human comfort; to determine what parameters were most important to comfort of human users of these spaces.	Environmental variables used in the study included air temperature and humidity, solar radiation, and wind speed (Herrington and Vittum, 1977).	Measurements were taken three times in four sites that differed in the size of green spaces
2	Greece, Drama 2006	To study the microclimatic conditions (temperature and relative humidity) and the feeling of thermal comfort in an urban green area compared to a central square. To determine the impact of vegetation on bioclimatic conditions.	Environmental parameters were measured using the THERMOIGROGRAFO thermographs (Georgi and Tzesouri, 2008).	Environmental parameters were measured constantly from 12/7/06 to 17/9/06.
3	Malaysia, Shah Alam 2013	To identify the impact of climate and personal factors on respondents' perception of climate and on thermal adaptation from the physiological and psychological perspectives.	1) Measurement of climatic parameters (air temperature, relative humidity, wind velocity, and solar radiation); 2) Interviewing of city park visitors; questions were related to demography, clothing, reasons for visiting the park, and the overall condition suitability with the microclimate (Rabiatul et al, 2013).	Environmental parameters were measured on days 70, 99, 134 and 161 of the year between 07:00 and 19:00. Interviews were conducted on the same days, with 73 interviews per day on average.
4	Brasil, Sao Paulo 2008	To identify the impact of shading trees on microclimate and thermal comfort in public spaces with various levels of density of green areas.	Meteorological stations were used to measure air temperature, humidity and wind speed. Solar radiation and surface temperature were measured additionally. Concurrently, pedestrians were interviewed regarding vegetation in the city (Spangenberg et al, 2008).	Monitoring was carried out on December 19, 2006 from 07:00 to 19:00, measurements were taken every 10 minutes in three areas (park, open air square and street)

Study 1 found that solar radiation, infrared radiation and wind speed are the most important to human comfort. All of these can be controlled to some extent by site design. Thus site design can be used to control human thermal comfort in outdoor urban spaces.

According to study 2, the average air temperature in parks is 2˚C lower, and relative humidity is about 4% lower than in the city center. Researchers concluded that vegetation and water are necessary elements to the formation of green spaces, and that these two elements enhance overall microclimate of the city.

Study 3 proved the human ability to adapt to climatic environmental conditions in urban green areas, because interviews showed that people define the temperature range of 21-39˚C as comfortable.

The last study listed in Table 1 demonstrated that trees have an insignificant impact on air temperature (1.1˚C), however, they have an explicit cooling effect on surface temperature (12˚C). Trees also reduce air speed by 45%.

General description of green areas in the city of Kyiv

The territory within the city of Kyiv that is covered by various plant species (including private gardens and households) is 49,133.52 hectares, or 58.80% of the overall city area. Kyiv has 122 parks, 379 public gardens and 80 boulevards that have two most essential functions in the city, environmental and recreational.

Table 2. Green spaces belonging to the nature reserve fund of the city of Kyiv, 2011

Type	Unit of measurement	2011
Public green spaces (parks, public gardens, specialised parks)	hectares	5,306.5
Public green spaces	m^2/capita	19.19
Forests and parks	thous. hectares	34,325.1
Forests and parks	m^2/capita	124.12
Facilities belonging to the nature reserve fund	hectares	12,055.2
Number of facilities belonging to the nature reserve fund	facilities	111

Approximately 50% of parks in Kyiv (2,670.57) belong to the nature reserve fund (NRF), where 12 parks are of national importance and 14 parks are of local importance (Concept of Strategic Development of the City of Kyiv, 2010).

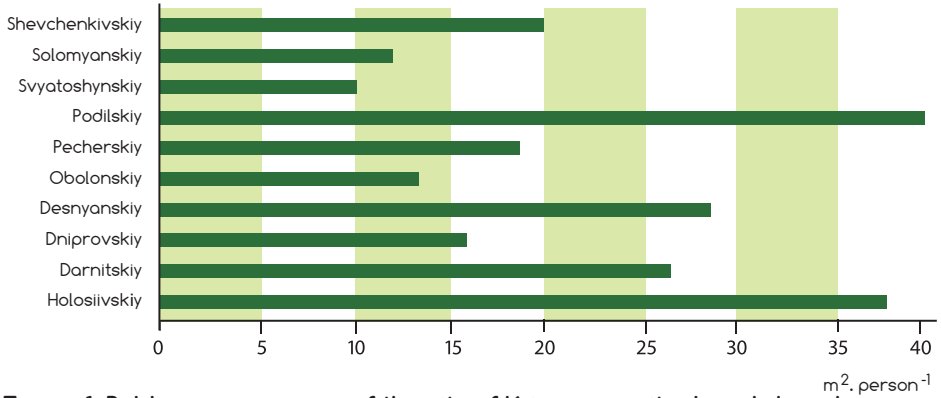


Figure 1. Public green spaces of the city of Kyiv per capita, breakdown by administrative districts (according to inventory records as of January 1, 2014 (Lesnik and Girs, 2015))

According to Kyivzelenbud, in 2014 Podilskiy and Golosiyivskiy Districts had the largest area of green spaces per capita among all administrative districts of Kyiv. Svyatoshynskiy District was the least green one.

Local level:

microclimate and resilience of various species of park trees to heatwaves in the city of Kyiv

According to the overview of 43 streets of Kyiv conducted by forest experts in 2014, most popular species are lime tree (39.0%), horse chestnut (22.2%), and black poplar (20.8%), which combined make up 82.6% of overall vegetation. These are followed by maple (Norway maple (4.0%) and silver maple (3.8%)) and necklace poplar (5.1%). Share of the remaining 7 species is 4.5% (Lesnik and Girs, 2015).

Which of these park tree species have the best resilience to hot weather? To find this out, in July 2016 we measured the speed of carbon dioxide absorption by leaves of five tree species in the Golosiyivskiy District: Norway maple *(Acer platanoides),* (2) horse chestnut *(Aesculus hippocastanum),* (3) small-leaved

lime *(Tilia cordata)*, (4) black locust *(Robinia pseudoacacia)*, and (5) black poplar *(Populus nigra L.)*.

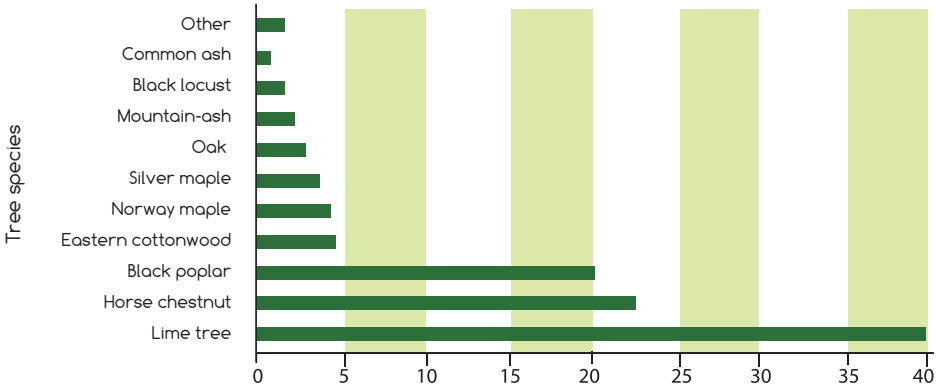


Figure 2. Breakdown by tree species planted in the streets of the city of Kyiv, %

Speed of CO_2 absorption and release by a leaf can be determined using equipment that measures concentration of carbon dioxide inside a special chamber where the leaf is placed. This ratio of absorption and release gives estimation of the tree's physiological activity. On sunny hot days when air temperature was within the range of 30-35˚C, we measured 15 trees of average age (three leaves from three trees of every specie) to ensure the statistic accuracy of the results obtained.

Figure 3. Measuring the ratio of CO_2 absorption and release by leaf surfaces of various species of park trees (July, 2016)

Table 3. Ratio of CO_2 assimilation and release on leaf level, μmol CO_2 $m^{-2}c^{-1}$

	Tree 1	Tree 2	Tree 3	Average value	Standard deviation
Maple	-0.005	-0.009	-0.007	-0.007	0.002
Chestnut	-0.013	-0.014	-0.013	-0.013	0.001
Poplar	-0.019	-0.025	-0.013	-0.019	0.006
Lime	-0.010	-0.018	-0.005	-0.011	0.006
Black locust	-0.009	-0.012	-0.019	-0.013	0.005

Negative values obtained mean that at the time of measuring the tree leaves were absorbing more of CO_2 than they were releasing. For the city overall this means that during heatwaves these tree species can serve as absorbers of carbon dioxide high concentrations of which suppress human activity and which is greenhouse gas (traps heat in the atmosphere). Comparison of values related to various tree species shows that black poplar is the biggest carbon dioxide absorber; it is followed by horse chestnut and black locust – both produced the same values; then goes small-leaved lime, and the least of CO_2 is absorbed by maple.

Table 4. Microclimatic parameters in the study location (Golosiyivskiy District, 50 S. Kovalevska Street, 50°22'51.8"N 30°28'14.1"E)

Time of measurement	Air temperature, °C	Soil temperature, 10 °C	Relative humidity, %	CO_2 content in the air, ppm
12:50-13:20	31,0	23,57	49	430
13:30-13:50	31,0	23,87	53	445
14:00-14:30	32,7	22,73	49	455
14:30-15:00	32,7	22,27	49	445
15:20-15:50	32,8	21,90	45	430
16:00-16:40	32,7	22,03	45	n/a
17:00-17:40	30,4	22,47	45	n/a

In terms of microclimate during the measurements, the situation was more or less the same throughout both days: air temperature was ranging between 30 and 33°C; soil temperature within 1 m from the tree trunk was 21–24°C, i.e. it was 7–10°C lower than the air temperature. Content of carbon dioxide in the

air varied slightly throughout the day and was approximately 440 ppm, which is typical for a big city, however, in a green district.

Table 5. Microclimatic parameters of area with asphalt coverage

Time	Asphalt surface temperature, ˚C	Light, lux[2]	Comment
14:00–15:00	45–48	700–747	open air space
	32–34	80–90	light shade
	29–33	55–65	deep shade
17:00	51	470	open air space

Additionally, we have tried to estimate how asphalt temperature (using an infrared thermometer) ranges depending on the degree of light – on the sun and in shade (using a light meter) on hot July days. We found that the difference between surface temperatures of an open air space and a shaded space in the period of time from 14:00 to 17:00 is 20˚C. This once again stresses the importance of urban green areas from the perspective of adaptation of city inhabitants to abnormal heat and climate change.

Figure 4. Measuring asphalt temperature of an open air space and in shade

Micro-district level:

cooling effect of green spaces in Kyiv measured using UAV thermal imaging

To find out how temperatures allocate around specific facilities such as buildings, trees or flowerbeds, we used thermal imager Flir Vue Pro and multi-rotor unmanned aerial vehicle (UAV) DJI Inspire-1 to carry out thermal imaging. Drone.UA experts were doing the thermal imaging from the height of 100 m, which helped produce thermal maps with spatial resolution of several centimeters. The UAV was also equipped with a normal camera, and thermal maps could therefore be compared with visual maps.

This method was used to study three residential blocks of Kyiv, two boulevards and one streets. These facilities differed by density and species of vegetation.

Figures 5 to 7 show visual and thermal maps of three residential blocks with various vegetation density. Density is calculated as estimated surface coverage by vegetation and is 7%, 35% and 47%.

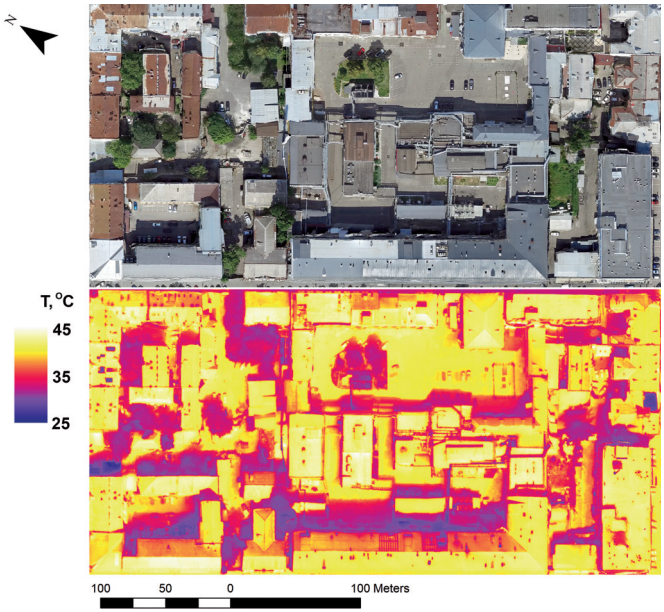


Figure 5. Visual and thermal map of the block on the northern side of Zhylyanska Street between Symona Petlyury Street and Lva Tolstogo Street. Estimated vegetation coverage is 7%.

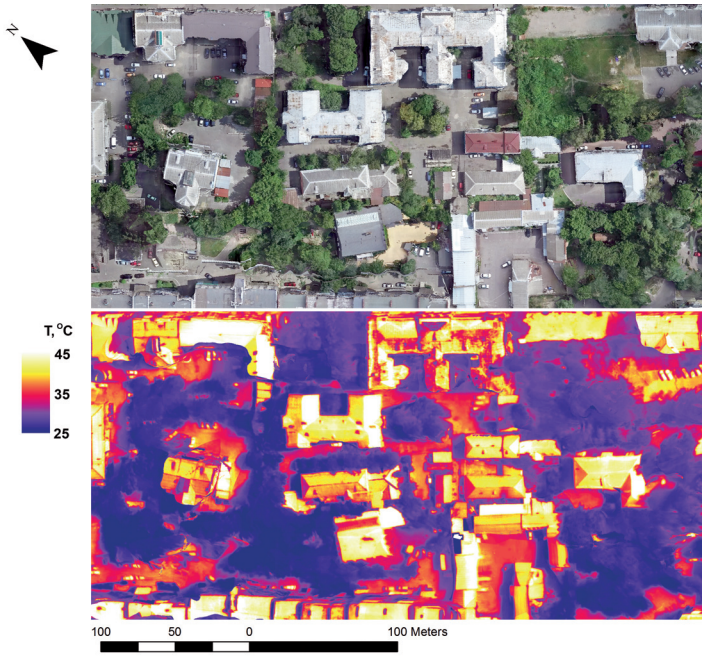


Figure 6. Visual and thermal map of the block on the northern side of Zhylyanska Street between Tarasivska Street and Pankivska Street. Estimated vegetation coverage is 35%.

The maps provide good illustration of several cooling capacity of plants:

1. Surface temperature of trees and grass plots is significantly lower than temperature of other surfaces. While temperature of asphalt and roofs can reach 45˚C and more, vegetation does not heat above 25–30˚C. This is primarily caused by higher reflection of sun light (vegetation is lighter than asphalt), and, secondly, by evaporation of water from the leaf surface, which results into temperature drop.
2. Tree surface is cooler than surface of grass plots. The reason is that the volume of canopies is larger than the volume of grass plots, and therefore trees have higher heating capacity per square meter of surface.
3. Most trees create good shade sufficient for significant cooling of the shaded surface. Temperature of shaded surfaces can be close to temperature of the plant itself, i.e. 25–30˚C.
4. Vegetation can reduce surface temperature even beyond the shaded area.

Around the shaded area there is a small zone where surface temperature is 3–5°C lower than in the remaining open area. This zone will be larger if surrounded by shaded areas from all or a few sides.

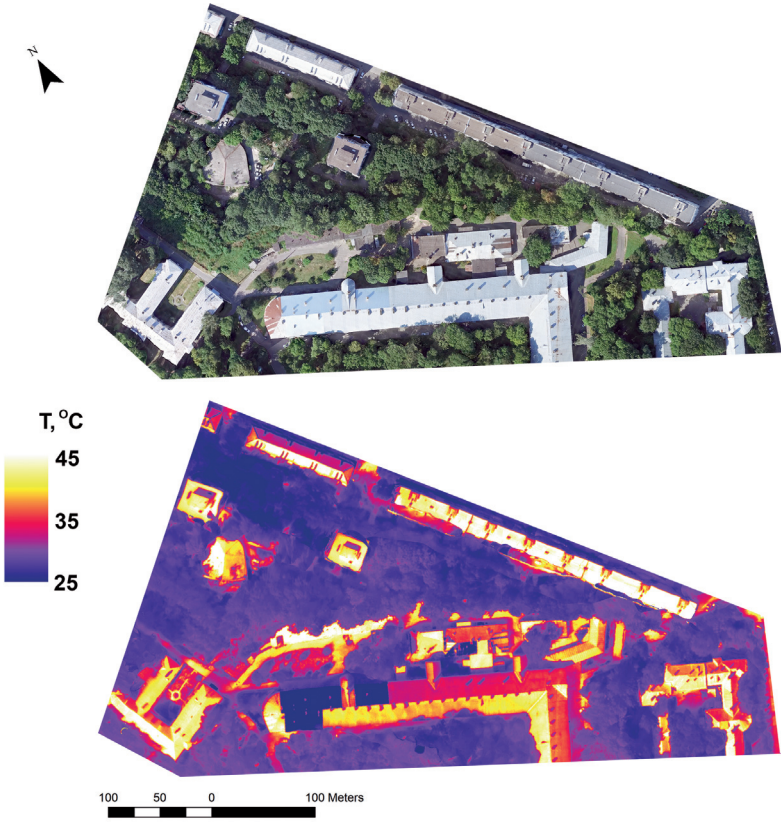


Figure 7. Visual and heating map of residential block and buildings of the military hospital on the corner of Lesya Ukrayinka Blvd and Novogospitalna Street. Estimated vegetation coverage is 47%.

Cooling zones are studied more thoroughly on linear objects. Figure 8 represents visual and heating maps, and vegetation cooling zones of Antonovycha Boulevard, Taras Shevchenko Boulevard and Saksahanskogo Street.

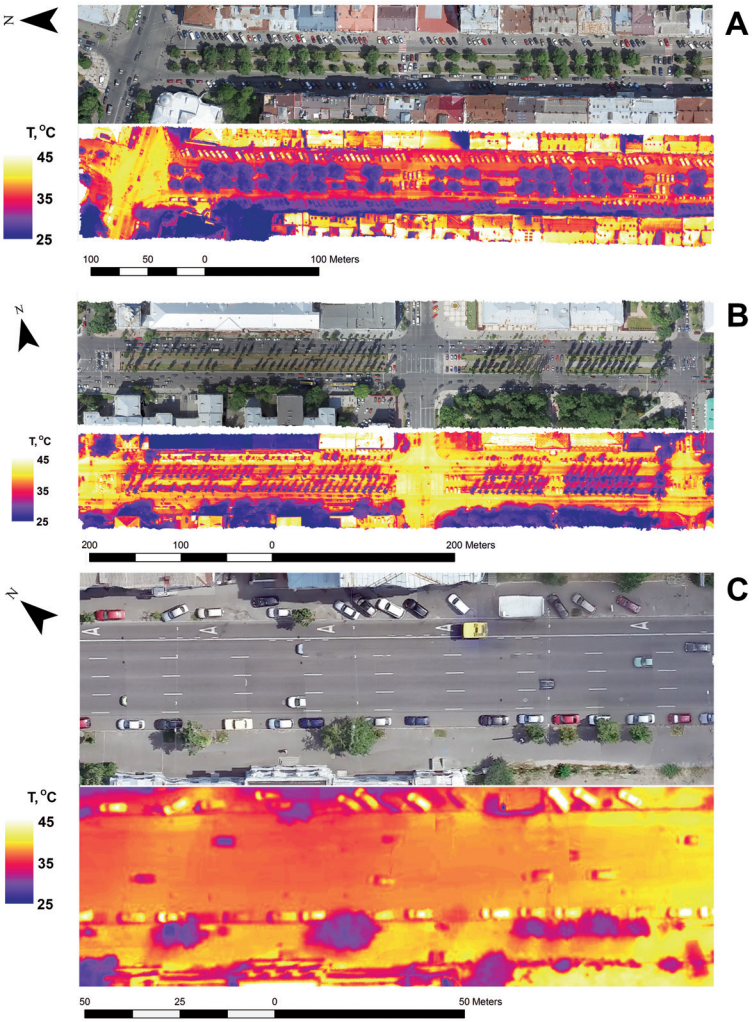


Figure 8. Visual and heating map of Antonovycha Boulevard (A), Tarasa Shevchenka Boulevard (B) and Saksahanskogo Street (C).

The vegetation consisted of the following species: Antonovycha Boulevard – horse chestnut; Tarasa Shevchenka Boulevard – poplar; Saksahanskogo Street – maple. Planting density is uneven on the selected street fragments.

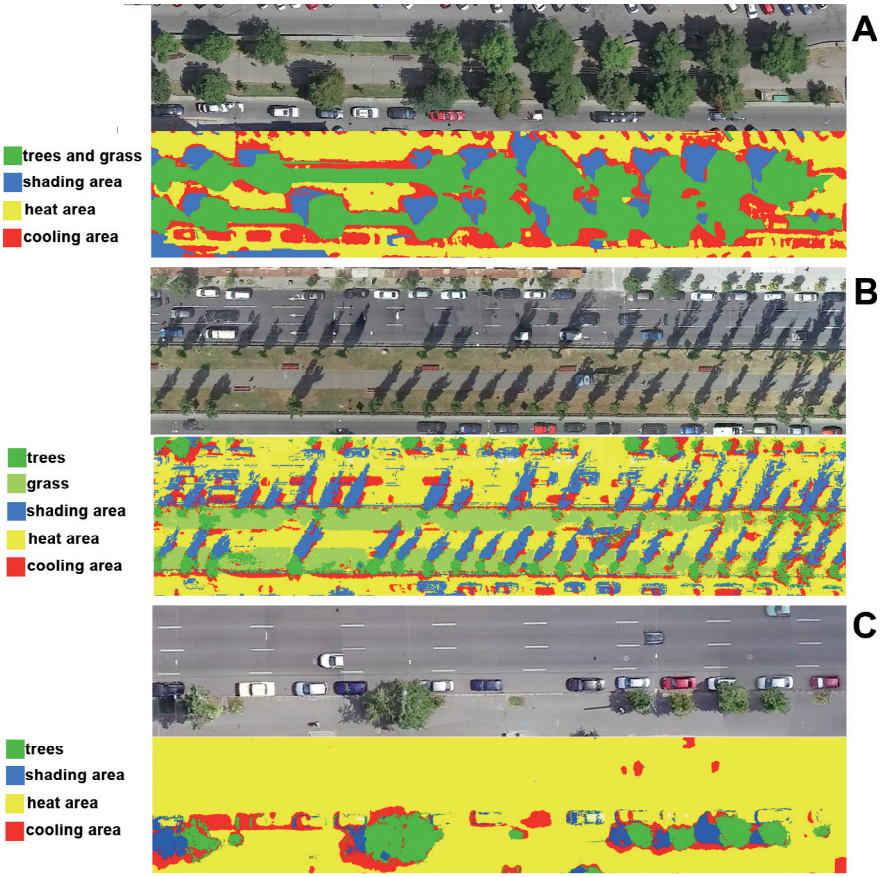


Figure 9. Visual map and allocation of the shading and cooling zones (outside of the shade), Antonovycha Boulevard (A), Tarasa Shevchenka Boulevard (B) and Saksahanskogo Street (C).

Analysis of these maps brings several conclusions:

- Horse chestnut obviously provides most shade and surface cooling. On the fragment of Antonovycha Street, trees with canopies of 8 to 12 m in diameter planted in two rows with frequency of 1 tree/15 m, provide cooling of the whole territory in between the trees. Estimated street coverage by vegetation is 68%. This value should be used as a benchmark to ensure the homogeneous cooling of territory.
- Poplar produces the least amount of shade. Even where planting density is

1 tree/7.5 m, cooling only occurs in shaded zones, which account for 10% to 30% of the surface depending on the position of the Sun.

- Maple provides sufficient shade, however its size is smaller compared to horse-chestnut, and therefore with the same planting density horse-chestnut will provide more efficient shading and cooling.

City level:
thermal pattern in Kyiv according to satellite imagery data

Surface temperatures observed in Kyiv in hot weather were determined using thermal images from space satellite Landsat-8. This data was provided by the Scientific Centre for Aerospace Research of the Earth, Institute of Geological Sciences, National Academy of Sciences of Ukraine. Figure 10 demonstrates the allocation of surface temperatures in Kyiv as of July 31, 2014 (Stankevych et al, 2015).

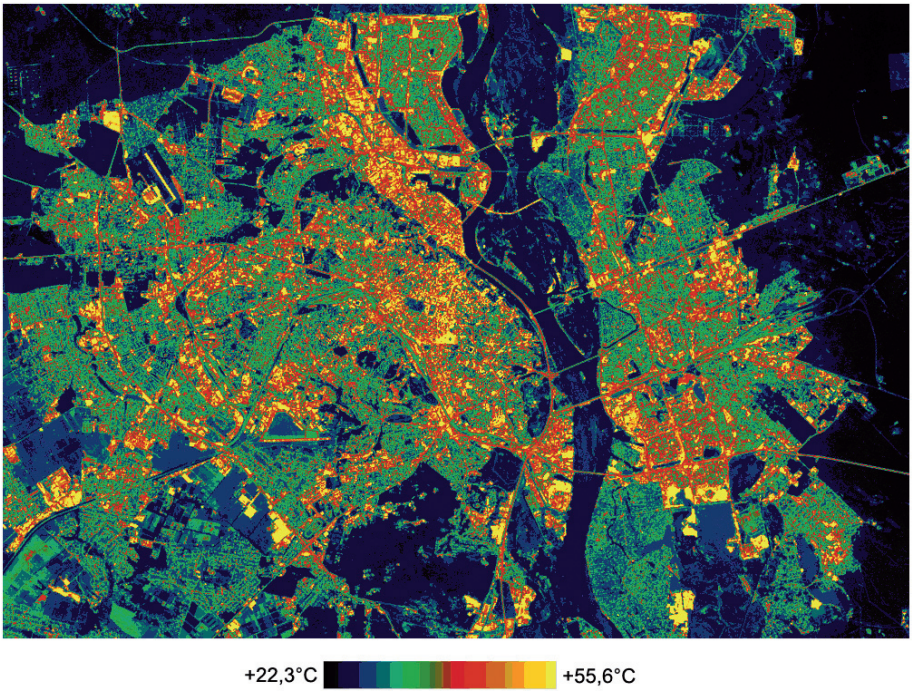


Figure 10. Surface temperatures in Kyiv according to the Landsat-8 satellite as of July 31, 2014 (Stankevych et al 2015)

In the hottest spots that are represented by man-made surfaces such as sand, building roofs, asphalt and concrete, temperature reached 56˚C on that day, while temperature of water surfaces and big forested areas was 23-25˚C. Heat islands (over 40˚C) are predominantly specific to industrial facilities, however they are also found on open roads and junctions.

For a better illustration of temperature trends we calculated average surface temperatures in Kyiv in summer months 2013 to 2015 (Figure 11). Most surfaces in Kyiv on average warm up to 30-40˚C. The highest temperatures are observed in industrial districts, newly constructed buildings on the left bank side, and the Obolon.

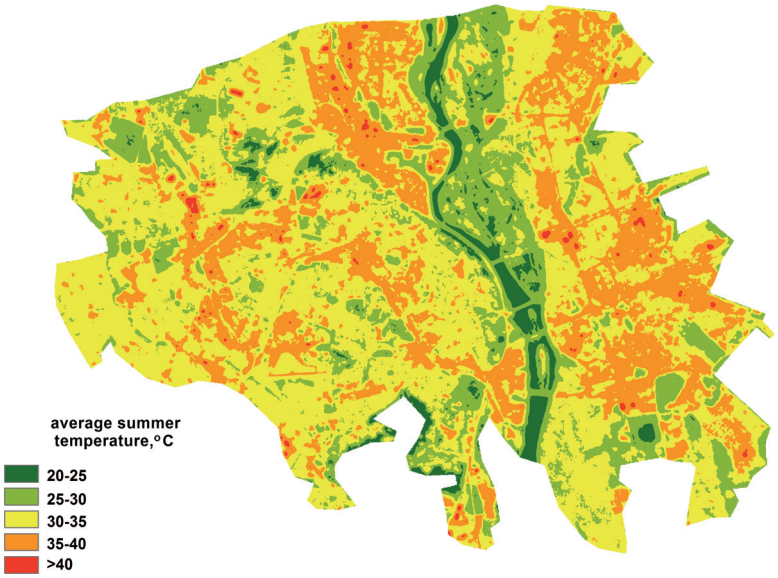


Figure 11. Average summer temperatures of surface in Kyiv over 2013-2015 according to satellite Landsat-8.

To identify the role of green areas in shaping the city's microclimate, we compared the average summer temperature within micro-districts, and the percentage of green areas in these micro-districts. The percentage of green areas was calculated using high spatial resolution imagery from satellite World View-2. Districts with predominantly private households were not covered in the study because the percentage of green areas there is regulated by household owners and is usually high.

Standards of green area sizes in the city of Kyiv

Explicit information regarding the established and actual size of all green areas in the city of Kyiv is not available. The 2020 General Plan for the City of Kyiv contains actual (as of 2001) and planned quantities of vegetation intended for public use only, i.e. parks, forests and public gardens. In particular, it indicates that the size of public green areas will be increased from 5,289.4 hectares in 2001 to 7,608.0 hectares before 2020, and the standard of coverage will, accordingly, grow from 20.3 m2/capita to 28.7 m2/capita. However, the standard of coverage is overstated, because it is calculated based on the official city population figures which are understated as compared to the real numbers. Appendix 5.2 of the State Construction Regulations contains standards for green areas intended for public and special use.

Structural elements	Green areas, %
1. Public green territories	
City parks	65-80
Children's parks	40-55
Memorial parks	30-65
Zoo gardens	15-40
Botanical gardens	40-70
Public gardens	75-85
Boulevards	60-75
Бульвари	60–75
2. Green territories of limited use	
Residential districts	At least 25
School territories	45-50
Territories of childcare facilities	45-55
Territories of public buildings	At least 40
Territories of educational institutions	Approximately 50
Territories of cultural institutions	40-60
Territories of sport sites and facilities	30-50
Territories of healthcare facilities	55-65
Green territories intended for special use: streets near sanitary and protected zones	At least 25 60-80

For purposes of this project, it is important to identify the size of green areas in territories of restricted use, specifically residential districts and popular public sites, because these places have the highest numbers of visitors. In particular, standard of green areas for residential districts is at least 25%, and at least 40% in public sites (shops, institutes, office buildings etc.).

Figures 12 and 13 demonstrate average summer temperatures and size of green areas in micro-districts, correspondingly. The most heated residential districts are in the Troyeschyna and Poznyaky: average summer temperature of surface there reach 35–37˚C. These micro-districts have the smallest size of green areas, 0-10%. Temperature in the range of 34–35˚C is also observed in the Obolon and central parts of the city. The size of green areas there is 10-15%. The lowest temperatures (30-33˚C) are found in the residential blocks of the Golosiyivskiy District, Borschagivka, Svyatoshyno, and Syrets. Surface temperature there does not rise above 33˚C, and green areas cover 20-40% of the territory.

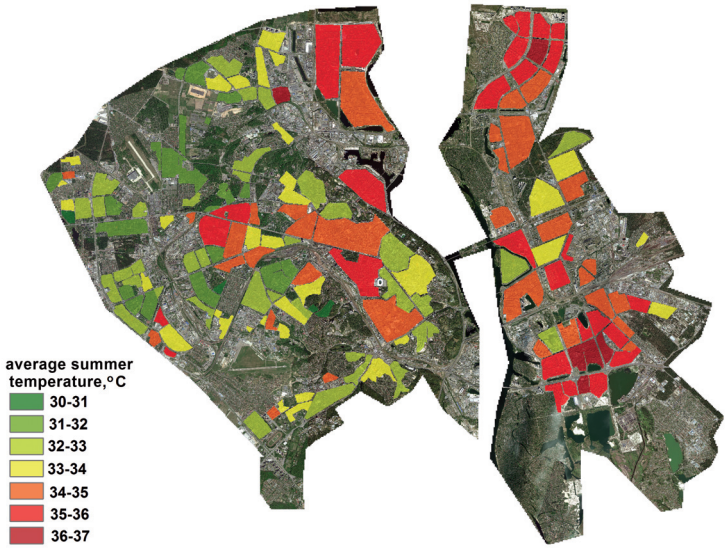


Figure 12. Breakdown of average summer surface temperatures in Kyiv over 2013-2015 by micro-districts (source: satellite Landsat-8).

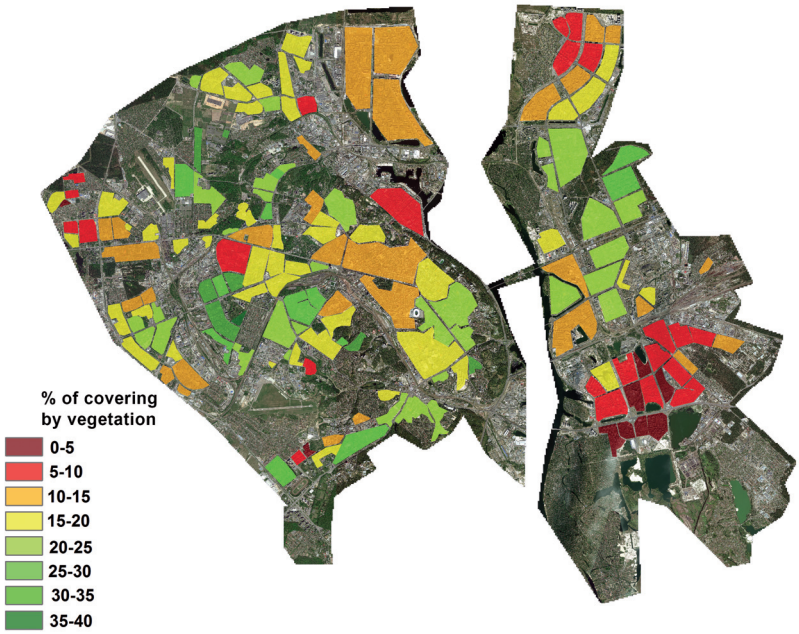


Figure 13. Percentage of green areas in micro-districts of Kyiv

Hence, temperature patterns in residential blocks clearly depend on the density of green areas. Most of newly built-up areas suffer from heat due to non-observance of standards applicable to the size of green areas within residential territories. Green areas are almost completely absent in the territories adjacent to plants, factories, major roads and junctions, which causes extremely high temperatures and creates a threat to health and life of people working or travelling in the city.

Legislative framework governing the management of urban green areas in Ukraine in the context of climate change

The notion of green areas in the Ukrainian laws

From the legal perspective, green areas are greened territories (as defined in the State Construction Regulations DBN 360-92**), i.e. land plots covered by trees, shrubs and lawns that are classified in city planning documents of the relevant city under a separate category; individual tree plantations that spatially do not belong to greened territories as to land plots with relevant intended use.

The Ukrainian legislation that governs urban green areas is very limited and is only developed with regard to city planning and city management. Environmental legislation does not contain any specific regulations addressing the issue of green areas and only to a partial extent envisaged their protection – as part of protection of specific facilities and territories that have the status of facilities and territories belonging to the nature reserve fund. Furthermore, Article 4 of the Forest Code of Ukraine defines that all plants within urban boundaries do not belong to lands of the state forest fund. The environmental scope of our study hence lies outside of the environmental legislation.

We are not considering legislative acts intended to protect green areas from cutting, calculation and charging of replacement cost, standards for preparation and planting, and some other groups of legislative acts that are not directly related to our study.

Classification of vegetation and regulatory documents applicable to green area management

In terms of functionality, comprehensive green areas (built-up territory, urban and sub-urban green areas) are usually classified as follows:

1. **Green territories of public use**: territories intended for general public, such as parks, gardens and boulevards.
2. **Green territories of limited use**: vegetation in residential areas, daily used places (educational facilities, office buildings, shops etc.) and places unfit for organized leisure, such as slopes and swamped areas. According to the official records, vegetation of limited use in Kyiv covers the area of 11,638.6

hectares and is an important element of the city's green areas. The largest and most important part of this type of vegetation is represented by green areas within residential territories which consist of green spaces inside residential blocks and green belts adjacent to buildings.

This study is mainly focused on green spaces in places of limited use – primarily, because these places are being constantly used by the biggest number of people, and secondarily because the management of these places is worst governed by law.

3. **Green territories of special use** – vegetation within territories owned by enterprises and defense facilities, or along railways. Vegetation of special use (total area 5,161.7 hectares) differs by types and functions.

Management of green spaces in Ukraine is governed by a number of regulations, laws and by-laws:

Document title	Adopted by	Effective date	Applicable to	Responsible authority
State Construction Regulations DBN 360-92**: "City Planning. Planning and Development of Urban and Rural Settlements"	Ministry of Construction, Architecture, Housing and Utilities of Ukraine	1/10/2006	Status 33; category 33; rural and urban green space standards	State governance authorities, local and regional governments of enterprises and institutions
2020 General Plan for the City of Kyiv	Kyiv City Council	28/03/2002	Actual and planned sizes of public green spaces	Kyiv City Council
Law of Ukraine on Urban Development	Verkhovna Rada of Ukraine	01/01/2006	Range of works related to engineering protection, clearance, drainage and greening of the territory	Ministry of Justice of Ukraine
Rules of Management of Urban Green Spaces in Ukraine (in pursuance of the Law of Ukraine on Urban Development)	Ministry of Construction, Architecture, Housing and Utilities of Ukraine	10/04/2006	Legal and organizational grounds of urban greening aimed to ensure beneficial living conditions	State Committee of Ukraine on Housing and Utilities Department for Development and Green Spaces

Rules of Maintenance of Residential Houses and Adjacent Areas (pursuant to the Law of Ukraine on the National Programme of Reforming and Development of Utility Services for 2004-2010 and the Decree of the President of Ukraine "On Regulations on the State Committee of Ukraine for Housing and Utilities")	State Committee of Ukraine for Housing and Utilities	17/05/2005	Management of plants in courtyards and in territories adjacent to houses from the external sides of blocks	Verkhovna Rada Committee
Kyiv City Development Rules (pursuant to the Code of Ukraine on Administrative Offences, Law of Ukraine on Urban Development, Law of Ukraine on Local Self-Governance in Ukraine, and Law of Ukraine on the Hero City of Kyiv, the Capital of Ukraine)	Kyiv City Council	25/12/2008	Restriction of business and other operations that may have an impact on green spaces	Kyiv City Council
Law of Ukraine on Nature Reserve Fund of Ukraine	Verkhovna Rada of Ukraine	16/06/1992	National nature parks, nature reserves, protected areas, natural landmarks, arboretums, botanical gardens, zoological parks and garden park landmarks	Ministry of Justice of Ukraine

State Construction Regulations DBN 360-92**

"City Building. Urban and Rural Planning and Development"

The key regulatory act that defines the status and categories of urban green areas and specifies the size of green territories to be encompassed by urban and rural planning structures.

The DBN 360-92 is among the most detailed and well-conceived regulatory acts that can be used for green area management. The core problem is the low level of enforcement and absence of liability for breaching the rules contained in the document.

Law of Ukraine on Urban Development

Article 1 of the Law defines that urban development is a set of works related to engineering protection, clearance, drainage and greening of the territory, and social, economic, organizational, legal and environmental measures aimed to improve micro climate, ensure sanitary purification, reduction of noise etc, that are taken within the urban area with the purpose of its reasonable use, proper management and protection, and creating appropriate conditions for protection and restoration of environment favorable to human habitation. As envisaged in Article 21 of the Law, elements (parts) of development facilities include green spaces along streets and roads, in parks, public gardens, alleys, boulevards, other public facilities, protection zones, and areas adjacent to buildings.

All green spaces within urban areas are subject to protection and renovation in course of any activities, with exception to the green spaces that were planted or grew within protected zones of overhead and cable lines, transformer stations, distributing points and devices. Records regarding green spaces are kept by local self-governance authorities (Article 28).

Significant share of requirements regarding the maintenance of green spaces is covered in by-laws; the Law mostly addresses the development, rather than creation, of green areas.

Rules of Management of Urban Green Spaces in Ukraine

The Rules define legal and organizational grounds for urban greening that are intended to ensure favorable living conditions.

The purpose for which the Rules were prepared is to protect and preserve green spaces in urban areas and outside, maintain the green spaces in healthy and appropriate condition, create and form highly decorative plants resilient to unfavorable environmental conditions (including climate change) (paragraph 1.2).

All green spaces within urban areas are subject to protection and renovation in course of any activities, with exception to the green spaces that were planted or grew within protected zones of overhead and cable lines, transformer stations, distributing points and enterprises (paragraph 7.1).

This instrument that defines parameters of planting stock for urban greening should be amended in terms of species of trees that are most resistant to the new and dynamic climatic conditions.

The Rules only apply to the intentionally planted green spaces, and therefore cause elimination of a part of trees and shrubs. This is particularly threatening when green areas of limited use are transferred to the category of public green areas. For example, in course of adoption of the 2010 Comprehensive Programme of Green Areas Development for the city of Kyiv (in 2007) the size of public green spaces was artificially overestimated (because during 2002-2007 many green areas were allocated for housing development (that involved the change of intended use). Many green areas of limited use were then added to public green areas, although most of these have natural origin. These green spaces are currently not subjected to any protection.

Rules of Maintenance of Residential Houses and Adjacent Areas

Part of green territories of special use and specific plants is located in courtyards and areas adjacent to buildings from external side of blocks. Unfortunately, this plant group is the most vulnerable. Inner yards of residential blocks are significantly shaded by buildings and do not have proper soil, because during construction they were part of the construction site; breathing of trees is significantly obstructed as the ground tends to be flattened by pedestrians and cars, salinized, and quickly freezes through without the natural layer of vegetation cover. Through these reasons vegetation of this type is in depressed state.

Management of such territories is regulated by the Rules of Maintenance of Residential Buildings and Adjacent Areas.[1] According to these Rules

[1] Decree of the State Committee of Ukraine for Housing and Utilities No.76 of May 17, 2005 "On approval of the Rules of Maintenance of Residential Buildings and Adjacent Areas".

snow removed from courtyards, lanes inside the residential blocks, and specific streets (with due regard to local conditions), may be piled on lawns and in free territories provided that the relevant vegetation is intact (sub-paragraph 3.5.18), which creates a visible threat to preservation of lawns due to salinization of soil that occurs upon piling of the snow removed from streets and sidewalks.

The Rules to a certain extent protect the green spaces, e.g. by prohibiting to pile any materials within areas covered by vegetation, throw garbage into flowerbeds, lawns and trails, damage plants, tie ropes and wires to trees, hang hammocks, attach advertising boards etc. (sub-paragraph 3.8.7). Owners of green areas are obliged to ensure the preservation, proper maintenance and renovation of vegetation; water lawns, flowerbeds, trees and shrubs in dry weather; prevent trampling of lawns and piling of construction materials, sand, garbage, snow and chipped ice on them; plant new trees and shrubs; make any layout changes that involve the change of the system of trails and placement of equipment only based upon duly approved designs and in compliance with all agrotechnical terms and conditions; in all cases, cut and re-plant trees and shrubs when required for maintenance and repair purposes in accordance with applicable laws; maintain any water reservoirs, if present in the relevant green area, clean and perform their complete cleansing at least once every 10 years; raise public awareness of careful use of green spaces; keep records of the vegetation with breakdown by area covered, species, age and condition (sub-paragraph 3.8.8).

Kyiv City Development Rules

The Kyiv City Development Rules approved by Resolution of the Kyiv City Council No. 1051/1051 of December 25, 2008 "On city development rules"[2] contain an explicit restriction of the business or any other operations that can influence the condition of green spaces. Entities responsible for the preservation and proper care of green spaces within the city of Kyiv are:

for public facilities owned by the state or utility enterprise: operators of these facilities (sub-paragraph 9.2.1); for territories owned by institutions, enterprises and organizations, including adjacent areas: institutions, enterprises and organizations (sub-paragraph 9.2.2.); for land plots allocated for construction purposes: developers or owners of these land plots (sub-paragraph 9.2.3.); for reserve urban lands: Kyiv Utility Association for Green Construction and Operation of Urban Green Spaces "Kyivzelenbud" and its

[2] http://kmr.ligazakon.ua/SITE2/l_docki2.nsf/alldocWWW/1EC945CF22CC4FD7C225756E006DE238?OpenDocument

units (sub-paragraph 9.2.4.); for private households and adjacent areas: their respective owners or users(sub-paragraph 9.2.5.).

Paragraph 9.3 obliges the owners (users, operators) of green spaces to:

- on due time cut tree branches in protected zones (within 1 m) of live wires and any tree branches that hide street and building signs from view;
- mow lawns from time to time as the grass reaches the height of 15 cm, leaving it at the height of 5 to 8 cm. Mowed grass must be removed within 3 days; plants should be watered in the morning before 9 AM, or in the afternoon after 6 PM;
- immediately remove any dead standing trees that pose a threat to human life and health or can cause financial damage to legal entities, with subsequent execution of relevant documents entitling the removal of such trees within three days;
- maintain temporary structures, small architectural forms, advertisement structures and garden amenities in technically fit condition, and wash and paint the above in spring;
- systematically remove volunteer trees (trees with root collar less than 5 cm are removed without compensation of replacement value);
- systematically remove mistletoes from trees;
- install decorative protective fencing in places where lawns are at permanent threat, and cover tree holes with decorative metal grates or install decorative holes around them;
- take measures to prevent and combat vegetation damage by pests and diseases; in case of placement of advertisement boards within green spaces the owner must establish and upkeep a flowerbed and a lawn covering at least 6 square meters around the board (or as designed);
- when liquidating failures of engineering networks, remove trees and plants located within protected areas immediately at their own cost and expense upon request of the contractor or owner of the engineering networks.

The following is prohibited in the territory of green space infrastructure facilities:

- driving and parking cars, motorcycles and motorbikes (except for special technological vehicles) (sub-paragraph 9.6.1.);
- watering plants if air temperature is 0˚C or below;
- digging any construction waste and piling construction materials, structures or equipment (sub-paragraph 9.6.2.);

- dumping waste, garbage, grass, tree branches, wood, leaves and snow anywhere outside designated areas (sub-paragraph 9.6.3.);
- pasturing domestic animals, walking and training animals outside the designated areas, horse riding (sub-paragraph 9.6.4.);
- burning dry plants, making fires and infringing other fire safety rules (sub-paragraph 9.6.5.);
- covering tree trunks with leaves, sweeping dead leaves into water sewage holes (sub-paragraph 9.6.6.);
- hang hammocks, swings, linen-drying ropes on trees, hammer nails into tree trunks, attach advertisement means, electrical wires, barbed wires and other things that may damage trees (sub-paragraph 9.6.7.);
- digging trees, shrubs and flowers out of the ground (9.6.8.);
- planting trees and shrubs without consent of the owner (user, operator) (sub-paragraph 9.6.9.);
- repairing, maintenance and washing of vehicles, cars and mechanisms outside of designated areas (9.6.10.);
- making passenger transport stops and parking vehicles on lawns, flowerbeds and other green spaces (sub-paragraph 9.6.11.);
- conducting any earth-moving, construction or other works without permission (clearance) for temporary disturbance of the area's infrastructure issued by the Main Department of Development of the city of Kyiv, with exception of works conducted by the Kyiv Utility Association for Green Construction and Operation of Urban Green Spaces "Kyivzelenbud" (9.6.12.);
- spilling any chemicals not intended for such use on sidewalks, paths, trails and other firm surfaces (sub-paragraph 9.6.13.);
- making gardens without authorization, producing juice or resin from trees, making mechanical damage to trees and flowers (9.6.16.);
- organizing games, sports competitions etc. (9.6.17.);
- destroying ant heaps and bird nests, catching and hunting birds and animals (9.6.18.).

Law of Ukraine on Nature Reserve Fund of Ukraine

Approximately 50% of Kyiv's parks belong to the nature reserve fund, and in addition to recreation also have the function of nature protection. Therefore these parks are governed by the Law of Ukraine on Nature Reserve Fund

of Ukraine. Territories of urban nature reserve fund can be represented by most of the categories envisaged by law, such as national nature parks, nature reserves, natural landmarks, arboretums, botanical gardens, zoological parks, and garden parks.

Individual important trees may also be protected as natural landmarks. Business operations (including renovation and replacement of plants) there is restricted by the Law and the relevant Regulations adopted for every object that belongs to the nature reserve fund.

Violation of legislation governing green areas

Laws on green area planning are rather peculiar and not properly detailed, and due to this violation of these laws is not common. In contrast to, for instance, land laws, which are infringed through allocation of green areas for construction purposes, or rules governing the removal of green spaces, formation of green areas as such is not a matter of conflict.

The Code of Ukraine on Administrative Offences (CUAO) envisages liability for infringement of state standards, rules and regulations governing urban development, and rules of urban territory development (Article 152); specifically, infringement of state standards, rules and regulations governing urban development, and rules of urban territory development entails, for individuals, a fine equivalent to twenty to eighty tax-exempt minimum incomes; and for public officials and private entrepreneurs, fifty to one hundred tax-exempt minimum incomes. Article 153 of the Code also contemplates liability for destruction of or damage to urban vegetation or other elements of green spaces; specifically, destruction of or damage to vegetation, individual trees, shrubs, lawns, flowerbeds and other elements of urban green spaces, failure to take measures for protection of the above, or unauthorized transfer of the above to any other places during construction works within specific places with green space elements, entails, for individuals, a fine equivalent to ten to thirty tax-exempt minimum incomes; and for public officials and private entrepreneurs, thirty to fifty tax-exempt minimum incomes.

Infringement of development rules means infringement of the following legislative acts:

- Law of Ukraine on Urban Development;
- Law of Ukraine on Regulation of City Building Operations No. 3038-VI of February 17, 2011;
- Ruling of the Cabinet of Ministers of Ukraine No. 1045 of August 1, 2006 “On approval of the Procedure for Removal of Trees, Shrubs, Lawns and Flowerbeds in Urban Areas”;

- Decree of the State Committee of Ukraine on Housing and Utilities No. 76 of May 17, 2005 "On approval of the Rules of Management of Residential Buildings and Adjacent Areas";
- Decree of the Ministry of Construction, Architecture, Housing and Utilities of Ukraine No. 105 of April 10, 2006 "On approval of the Rules of Maintenance of Urban Green Spaces of Ukraine";
- Decree of the Ministry of Housing and Utilities of Ukraine "On approval of the Methodology of Calculation of Restoration Cost of Vegetation" No. 127 of May 12, 2009;
- Kyiv City Development Rules approved by Resolution of the Kyiv City Council No. 1051/1051 of December 25, 2008 "On the Kyiv City Development Rules".

General conclusions and recommendations

To municipal utilities enterprises responsible for green spaces:

1. Many countries have developed a range of adaptation measures to build the resilience of people living in urban environments to temperature increase in summer months (Massey, 2012). These adaptation measures include:
   - weather observations;
   - increased readiness of municipal authorities in charge of public health;
   - public awareness raising;
   - changes in organizing of urban space.
2. One of essential elements of adaptation is the increase of green plants that shade dark heat absorbing surfaces (such as soil and asphalt), thus preventing the overheating of these surfaces. Furthermore, they create a special microclimate, regulating temperature patterns, reducing the amount of dust in the air, retaining the atmospheric moisture, and absorbing carbon dioxide (Bowler et al., 2010; Qiu et al., 2013).
3. Domestic researchers (Levon, 2004) revealed that the urban green spaces feature unreasonably low range of woody plant species – this is particularly relevant to streets and highways – and found that the woody plants currently available in collections of Ukrainian botanical gardens and arboretums could significantly expand the taxonomic composition of green spaces, and that diversity of the species planted in cities should be further expanded.
4. Gas exchange and thermal imaging research identified pros and cons of specific tree species. Poplar, horse chestnut and black locust turned out to be the most resilient (tolerant) to high temperatures. However, due to its pyramid shape poplar does not provide sufficient shade and surface cooling. Structure and shape of black locust canopy suggest that this specie will provide less shade than horse chestnut. Maple creates good shade, although it is vulnerable to heat stress. Horse chestnut is therefore the most efficient specie for temperature reduction purposes. It actively absorbs carbon dioxide and releases water during summer heatwaves, creating deep shading.
5. In case of horse chestnut, for uniform cooling of the area estimated coverage must be 70%, which is equivalent to 1 tree per 15 meters with canopy diameter of 8-12 m.

6. During summer heatwaves trees have lower surface temperature compared to lawns, and hence trees are a preferred vegetation option.

7. Greening of the area adjacent to residential buildings should include an option of vertical greening of southern and south-eastern walls; concrete should where possible used instead of asphalt in construction of passages and sidewalks; concrete surfaces or soil with addition of sand or wood chips should be used to make rest areas (Artamonov, 2013).

To legislative authorities:

1. Neither city planning laws, nor urban development regulations account for adaptation of green areas to global climate change; instead, city planning and development laws are the sphere where urban green spaces and vegetation can be adapted to new climatic conditions by increasing their resilience to global climate change.

2. Greening regulations contained in the State Construction Regulations must be binding upon all organizations whose operations are related to greening, including site developers, who should be primarily required to ensure the appropriate size of green spaces in residential districts. Many residential districts and public places in Kyiv are exposed to high temperatures during summer heatwaves. This is predominantly caused by infringement of the greening standards. In many relatively new residential districts the actual size of green spaces is 5-15% of the overall area instead of 25% as required by the applicable standard. Examples of such residential districts include Troyeschyna, Poznyaky, Obolon and individual new buildings across the city. However, even the standard of 25% of green spaces does not provide complete protection against uncomfortable temperatures (>30˚C). The recommended greening level to build resilience to climate change is 35-40%.

3. The Rules of Management of Urban Green Spaces in Ukraine that define the parameters of planting materials intended for urban greening purposes should be amended to include the tree species that are more resistant to the new and dynamic climatic conditions. The recommended amendments to the Rules should address the preservation of natural vegetation, natural precipitate, leaves and dead wood within green areas that are in their natural condition; preservation of hollow trees and other natural habitats. These points may become the basis for specific standards and regulations.

4. The Law of Ukraine on Urban Development: if a single law combining all regulations contained in effective by-laws on green spaces is approved, a part of the requirements contained in the Law of Ukraine on Urban Development should be transposed to the new law. Furthermore, Article 28

of the Law should be supplemented with a provision introducing a binding requirement to keep records of volunteer plants and apply to the Law to these plants in the same way as to cultivated plants.

5. The Kyiv City Development Rules: although the Rules are rather well-conceived, control over compliance with them is imposed on a body that is the main administrator of both green spaces and vegetation. Compliance with these requirements is controlled by district utilities enterprises responsible for green space management and utilities enterprises of Kyivzelenbud. Hence, it is necessary to introduce a mechanism of external control over implementation of the Rules. Satellite monitoring based on imagery with high spatial resolution can be used as an independent tool to control the condition of green spaces.

References

1. Artamonov B.B. (2013). Analysis of impact of micro climatic zones on urban climate in conditions of global climate change. Scientific Bulletin of the National Forestry University of Ukraine, 23,13 133–137. http://nbuv.gov.ua/UJRN/nvnltu_2013_23

2. Gorniy V.I., Lyalko V.I., Kritsuk S.G., Latypov I.S., Tronin A.A., Filippovich V.E., Stakevych S.A., Brovkina O.V., Kiselyov A.V., Davida T.A., Lubskiy N.S., Krylova A.B. (2016). Forecast of thermal response of urban environements of Saint-Petersburgh and Kyiv to climate change (based on EOS and Landsat satellite imagery). Current problems of remote sensing of the Earth from space. 2013. T. 13. No.2. Pages 176–191 http://d33.infospace.ru/d33_conf/sb2016t2/176-191.pdf, DOI: 10.21046/2070-7401-2016-13-2-176-191

3. Levon F.M. (2004). Biological and environmental basics for making green spaces in urban and technogenic environments. Doctoral thesis, Agriculture. Lviv.

4. Lesnik O.M., Girs A. (2015). Analysis of green space coverage in the city of Kyiv. Scientific Bulletin of the University of Bioresources and Nature Use of Ukraine. Series: Forestry and Ornamental Gardening, 216, 15–21 http://nbuv.gov.ua/UJRN/nvnau_lis_2015_216(1)__4

5. Stakevych S.A., Filippovich V.E., Lubskiy N.S., Krylova A.B., Kritsuk S.G., Brovkina O.V., Gorniy V.I., Tronin A.A. (2015). Intercalibration of methods of restoration of thermodynamic temperature of urban area surface based on thermal satellite imaging. Ukrainian Journal of Remote Sensing of the Earth, 7, 12–21. http://irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=UJRN&P21DBN=UJRN&IMAGE_FILE_DOWNLOAD=1&Image_file_name=PDF/ukjdzz_2015_7_4.pdf

6. Filippovich V.E., Krylova A.B. (2014). Study of thermal field of the city of Kyiv based on satellite sensing imagery in IR range as a component of analysis of environmental condition of an urban territory. Collection of study papers of the 13th International Scientific Conference "Advanced Information Technologies for Management of Environmental Security, Nature Use and Emergency Measures", Kyiv, 16–28. http://itgip.org/wpcontent/uploads/2013/11/Book_small.pdf

7. Shevchenko O., Vlasyuk O., Stavchuk I., Vakolyuk M., Ilyash O., Rozhkova A. (2014). Evaluation of vulnerability to climate change: Ukraine. Climate Forum East, Working Group of Civil Ogranisations on Climate Change. http://climategroup.org.ua/wp-content/uploads/2014/07/ukraine_cc_vulnerability.pdf

8. Bowler, D.E., Buyung-Ali, L., Knight, T.M., and Pullin, A.S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning 97, 147–155. http://dx.doi.org/10.1016/j.landurbplan.2010.05.006.

9. Georgi, N., Tzesouri, A. (2008). Monitoring Thermal Comfort in Outdoor Urban Spaces for Bioclimatic Conditions Environment. 1st WSEAS International Conference on landscape architecture, Algarve, Portugal, 98–103. http://www.wseas.us/e-library/conferences/2008/algarve/LA/13-588-398.pdf

10. Herrington, L.P., Vittum, J.S. (1977). Human Thermal Comfort in Urban Outdoor Spaces. Proceedings of the conference on metropolitan physical environment, Upper Darby, PA, USA, 130-138. http://www.nrs.fs.fed.us/pubs/gtr/gtr_ne25/gtr_ne25_130.pdf

11. Luke Howard, The climate of London, deduced from Meteorological observations, made at different places in the neighborhood of the metropolis, 2 vol., London, 1818-20

12. Jylha, K., Fronzek, S., Tuomenvirta, H., Carter, T.R., and Ruosteenoja, K. (2008). Changes in frost, snow and Baltic sea ice by the end of the twentyfirst century based on climate model projections for Europe. Climatic Change, 86, 441–462. http://link.springer.com/article/10.1007%2Fs10584-007-9310-z

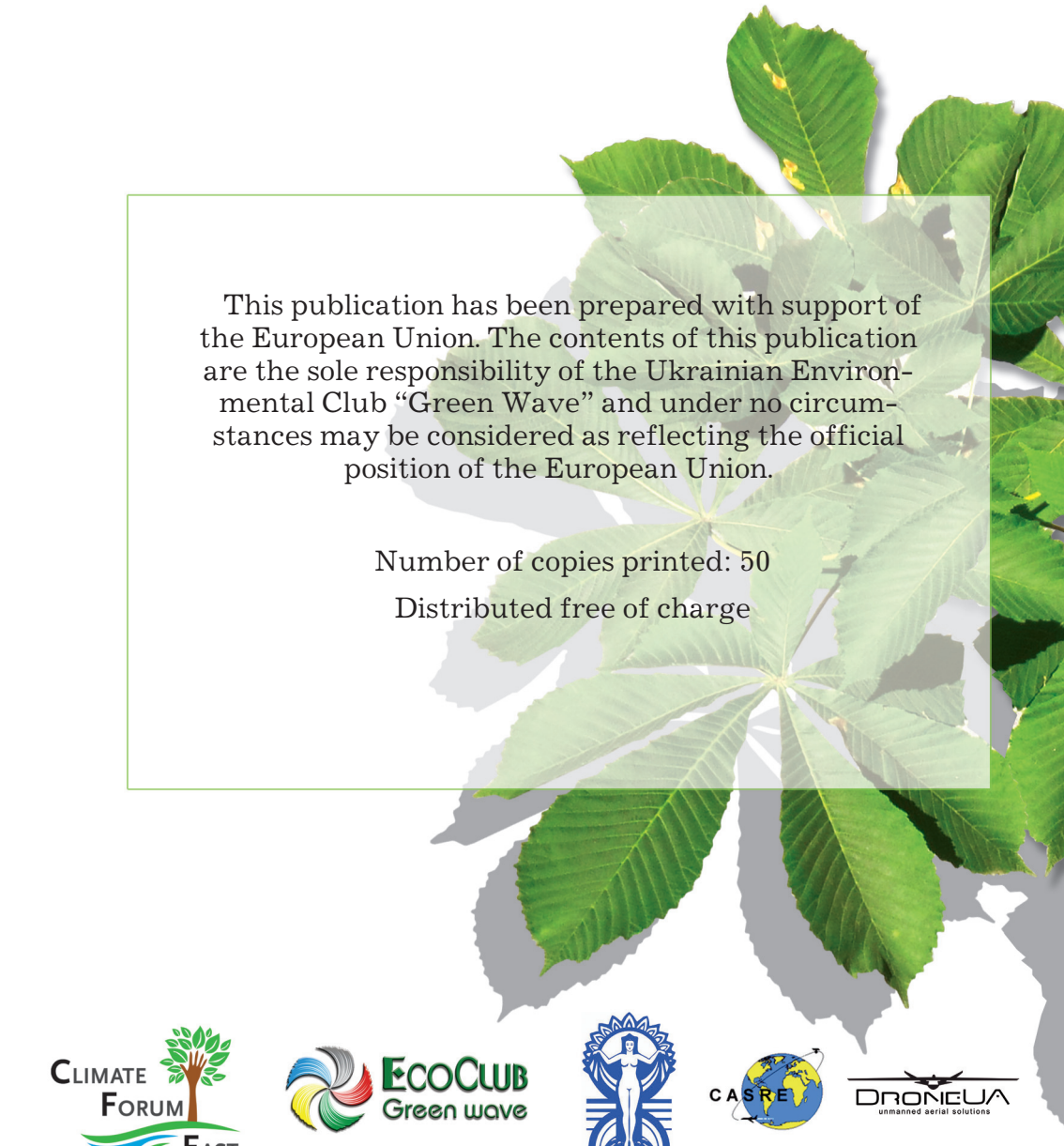
13. Massey, E.E. (2012). Experience of the European Union in Adaptation to Climate Change and its Application to Ukraine. Report of OSCE. http://www.osce.org/secretariat/93302?download=true.

14. Qiu, G., Li, H., Zhang, Q., Chen, W., Liang, X., and Li, X. (2013). Effects of Evapotranspiration on Mitigation of Urban Temperature by Vegetation and Urban Agriculture. Journal of Integrative Agriculture, 12, 1307–1315. http://dx.doi.org/10.1016/S2095-3119(13)60543-2

15. Rabiatul, A. N., Sabarinah, S. A., Azni Z. A. (2013). Adaptive Outdoor Thermal Comfort at an Urban Park in Malaysia. Journal of Asian Behavioural Studies, 10, 1–15. http://fspu.uitm.edu.my/cebs/images/stories/cebs/jabsv3n10mayjune2013c1.pdf

16. Spangenberg, J., Shinzato, P., Johansson, E. and Duarte, D. (2008). Simulation of Influence of Vegetation on Microclimate and Thermal Comfort in the City of San Paolo. SBAU, Piracicaba 2, 1–19. http://www.revsbau.esalq.usp.br/artigos_cientificos/artigo36.pdf

17. Stankevich, S.A., Filippovich, V.E. (2013). Infrared satellite imaging for the study of urban heat islands in Ukraine. Proceedings of 8th International Green Energy Conference (IGEC-8), Kiev, 219–223. http://www.academia.edu/23405138/Infrared_Satellite_Imaging_for_the_Study_of_Urban_Heat_Islands_in_Ukraine



This publication has been prepared with support of the European Union. The contents of this publication are the sole responsibility of the Ukrainian Environmental Club "Green Wave" and under no circumstances may be considered as reflecting the official position of the European Union.

Number of copies printed: 50

Distributed free of charge

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This project is funded by the European Union

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