REMOTE SENSING IN BIOMETEOROLOGY

Alexandru TUDOR

"Henri Coandă" Air Force Academy, Braşov, Romania (alexandru.tudor@afahc.ro@afahc.ro)
ORCID: 0009-0001-1471-2549

DOI: 10.19062/1842-9238.2022.20.2.1

Abstract: *Remote sensing is a powerful tool used in biometeorology to study the interactions between the atmosphere and living organisms, particularly plants. Through satellite-based sensors, researchers can observe and analyze a range of biophysical parameters related to vegetation, such as leaf area index, biomass, vegetation cover, and land surface temperature. This data can be used to estimate plant growth, productivity, and water use efficiency, as well as monitor environmental conditions, such as drought, heat stress, and air pollution. Remote sensing is used in the development of crop models for agricultural management and to study the impact of climate change on plant communities and ecosystems. By tracking changes in vegetation cover and productivity, as well as changes in phenology, remote sensing helps researchers identify optimal planting times, irrigation schedules, and predict crop yields.*

Keywords: *remote sensing, biometeorology, atmosphere, satellite-based sensor, climate change, seasonal biology, land surface temperature (LST), climate change.*

1. INTRODUCTION

Remote sensing is a powerful tool in biometeorology that allows researchers to observe and analyze vegetation and other environmental variables at large spatial and temporal scales. Biometeorology is the study of the interactions between the atmosphere and living organisms, particularly plants, and how these interactions affect the climate and weather. [1].

Remote sensing technologies, such as satellite-based sensors, can provide data on a range of biophysical parameters related to vegetation, including leaf area index (LAI), biomass, vegetation cover, and land surface temperature (LST). These data can be used to estimate plant growth, productivity, and water use efficiency, as well as to monitor environmental conditions, such as drought, heat stress, and air pollution.[1][2]

Remote sensing is used in biometeorology in the development of crop models for agricultural management. These models use remote sensing data, along with weather and soil information, to predict crop yields and identify optimal planting times and irrigation schedules.Another example is the use of remote sensing to study the impact of climate change on plant communities and ecosystems. Remote sensing data can help researchers track changes in vegetation cover and productivity, as well as changes in phenology (the timing of seasonal events, such as leaf emergence and flowering). [3][4] [5].

2. REMOTE SENSING

Remote sensing has become an important tool in biometeorology for studying the complex interactions between the atmosphere and living organisms, and for monitoring and predicting changes in the environment over time. Remote sensing is the process of collecting data about the environment without physically being present. In biometeorology, remote sensing is used to collect data on the Earth's surface and atmosphere to study the impacts of weather and climate on living organisms. [4] [5]

Different remote sensing techniques can be used to monitor changes in vegetation, land use, and weather patterns over time, providing valuable information for biometeorologists. For example, satellite imagery can be used to track changes in vegetation cover and identify areas affected by drought or other weather-related stressors. In addition, it can be used to measure various atmospheric parameters, such as temperature, humidity, and air pressure, which can help researchers to better understand the impacts of weather and climate on living organisms. For example, remote sensing data can be used to track the movement of air masses, which can impact the distribution and migration patterns of birds and other animals. [6]

The use of remote sensing in biometeorology has led to a better understanding of the complex relationship between the natural environment and living organisms, and has enabled researchers to develop more accurate models and predictions of how weather and climate impact the health, behavior, and well-being of different species. [3][4]

3. FURTHER USE OF REMOTE SENSING APPLIED TO BIOMETEOROLOGY FILEDS

Remote sensing provides a way to measure and monitor a variety of environmental variables over large spatial and temporal scales. Some of the key ways in which remote sensing can be applied in biometeorology include:

Vegetation monitoring: The use of remote sensing can enable the measurement of vegetation indices, including but not limited to the normalized difference vegetation index (NDVI) and leaf area index (LAI), which offer valuable insight into the extent and condition of vegetation coverage. These indices can be used to monitor changes in vegetation productivity, health, and distribution, and to identify areas of drought stress or other environmental stressors. [7][8]

Land surface temperature (LST) mapping: Remote sensing can be used to measure LST, which is an important parameter for understanding biophysical processes such as evapotranspiration and energy balance. LST mapping can be used to identify areas of urban heat island effect or to monitor changes in temperature associated with land cover changes or climate change.

Crop monitoring: Remote sensing can be used to monitor crop health and productivity, by measuring parameters such as leaf chlorophyll content and canopy temperature. These measurements can be used to optimize irrigation and fertilizer use, and to predict crop yields.

Phenological monitoring: Remote sensing can be used to track the timing of seasonal events, such as leaf emergence and flowering, which can provide important information on changes in plant growth and climate patterns.

Air quality monitoring: Remote sensing can be used to monitor air quality, by measuring parameters such as atmospheric particulate matter and ozone concentration. These measurements can be used to identify areas of high pollution and to assess the impact of pollution on vegetation and human health.

Remote sensing provides a powerful tool for monitoring and analyzing environmental variables related to biometeorology, and can help researchers better understand the complex interactions between living organisms and the atmosphere. [9][10] [11]

4. USING LST MAPPING IN BIOMETEOROLOGY

Land surface temperature (LST) mapping is an important tool in biometeorology, as it provides information on the temperature of the Earth's surface, which can impact the energy balance between the surface and the atmosphere. Some of the key ways in which LST mapping is used in biometeorology include:

Urban heat island effect: LST mapping can be used to identify areas of urban heat island effect, where cities and other developed areas are significantly warmer than surrounding rural areas due to factors such as increased energy use, reduced vegetation cover, and increased impervious surfaces.

Drought monitoring: LST mapping can be used to monitor drought conditions, as areas experiencing drought tend to have higher LST values due to reduced vegetation cover and soil moisture. [12][13]

Evapotranspiration: LST mapping can be used to estimate evapotranspiration rates, which is the combined loss of water from the Earth's surface through evaporation and plant transpiration. LST mapping can be used to estimate the amount of energy used for these processes, which is an important parameter for understanding the water balance in ecosystems.

Climate change impacts: LST mapping can be used to monitor changes in temperature associated with climate change, such as changes in the timing and duration of the growing season, or changes in the distribution of vegetation types.

Vegetation health: LST mapping can be used to monitor vegetation health, as changes in LST can indicate changes in plant water stress, disease, or other factors affecting vegetation health.

LST mapping is a valuable tool in biometeorology for monitoring and analyzing the impacts of environmental factors on the Earth's surface temperature and the associated biophysical processes. [13][14]

5. HEAT STRESS AND URBAN HEAT. THERMAL PERCEPTION STUDY OF URBAN AREAS

Thermal perception in urban areas is an important area of study in biometeorology, as it relates to the way that people experience and respond to temperature in urban environments. Some of the key ways in which biometeorology researchers study thermal perception in urban areas include:

Heat stress assessments: Biometeorologists use thermal perception data to assess the potential for heat stress in urban areas, which can help city planners and public health officials to develop strategies for mitigating the negative impacts of heat on human health. [30]

Thermal comfort mapping: Biometeorologists use data on thermal perception to create maps of thermal comfort in urban areas, which can help city planners and architects to design buildings and public spaces that are more comfortable for people to use in different weather conditions. [30][31]

Urban heat island effect: Biometeorologists study the effect on urban heat island, which is the phenomenon of warmer areas in urban environment than surrounding rural areas due to factors such as increased energy use and reduced vegetation cover. This can lead to increased thermal discomfort for urban residents, and biometeorologists study ways to mitigate this effect through urban greening and other strategies. [32][33]

Microclimate monitoring: Biometeorologists use sensors and other technology to monitor microclimates in urban areas, which can help to identify areas of high thermal discomfort and inform strategies for reducing heat stress.

Human behavior and adaptation: Biometeorologists study the way that people adapt to and respond to different thermal conditions in urban environments, such as the use of air conditioning or changes in outdoor activities.

The examination of how humans perceive temperature in urban settings is a significant subject in biometeorology investigation. Its significance lies in the impact it has on the health and welfare of people living in urban areas, and on the planning and administration of cities in the context of a changing climate. [33][34][35]

6. SATELLITE IMAGERY

Satellite imagery is a valuable tool in biometeorology as it allows researchers to monitor large-scale weather patterns and changes in vegetation and land use over time. This data can then be used to study the impacts of weather and climate on living organisms, including humans, animals, and plants. For example, satellite imagery can be used to track the distribution and movement of weather systems, such as hurricanes and typhoons, which can have a significant impact on human populations and ecosystems. Satellite data can also be used to monitor changes in vegetation cover and land use, which can provide insights into the impacts of climate change and human activities on ecosystems and wildlife. [27]

It can be used to monitor environmental conditions in real-time, providing early warning systems for natural disasters, such as droughts, floods, and wildfires. This data can help inform decision-making processes and enable communities to prepare and respond to potential threats.

Biometeorology relies heavily on satellite imagery as a critical resource to better understand the intricate interactions between the environment and organisms, aiding in the creation of precise models and forecasts of the effects of weather and climate on various species' health, behavior, and overall welfare. [28][29]

7. URBAN MAPING

Urban mapping is the process of creating detailed maps of urban areas, including buildings, streets, and infrastructure. In biometeorology, urban mapping is used to study how the built environment affects local weather and climate, as well as the health and well-being of urban populations. [24][25]

Urban mapping is used to identify areas of the city that are more susceptible to heat island effects, where temperatures are significantly higher than surrounding areas due to the presence of buildings and other infrastructure. This information can then be used to develop strategies to mitigate the impacts of heat on urban populations, such as the installation of green roofs and other urban green spaces.Urban mapping can also be used to study how air pollution levels vary across different neighborhoods and urban areas, providing insights into how these factors impact the health and well-being of residents. This information can be used to inform policies and interventions to reduce air pollution and improve public health.

By using this tool in biometeorology, it’s providing valuable insights into the complex relationship between the built environment, weather and climate, and the health and well-being of urban populations. By understanding these relationships, researchers and policymakers can develop strategies to improve the resilience and sustainability of urban areas, while also promoting the health and well-being of urban residents. [24][26]

8. URBAN FOOTPRINT MAPPING

Urban footprint mapping is a process of mapping the extent and characteristics of urban land use, often using remote sensing and geographic information systems (GIS) technologies. In biometeorology, urban footprint mapping is used to understand the impacts of urbanization on the environment and human health.

Urbanization can lead to significant changes in the local climate, including increased temperatures, altered wind patterns, and changes in precipitation. Urban footprint mapping can help identify areas that are particularly vulnerable to these impacts, such as neighborhoods with low levels of green space or areas with a high concentration of impervious surfaces like roads and buildings. By analyzing the extent and characteristics of urban land use, researchers can also identify areas where urban development may be encroaching on sensitive ecosystems or agricultural land, and develop strategies to promote more sustainable land use patterns.

It can also be used to study the distribution of environmental health hazards in urban areas, such as air pollution and heat stress, and to develop targeted interventions to address these hazards and promote public health.

This tool allows for a comprehensive understanding of the effects of urbanization on both the environment and human health. This knowledge can be used by researchers and policymakers to devise effective strategies aimed at promoting sustainable and healthy urban development. [26]

9. LANDSAT SATELLITES

Landsat is a series of Earth observation satellites operated by the United States Geological Survey (USGS). The Landsat program provides a continuous stream of moderate-resolution imagery of the Earth's land surfaces, helping scientists, resource managers, and policymakers make informed decisions about natural resources and the environment. The satellites are in a polar orbit, circling the Earth from north to south and taking images of the same areas at regular intervals. The latest Landsat satellite, Landsat 9, was launched on September 27, 2021, and it is now in operational mode.

The Landsat program has several operational components that work together to provide continuous and reliable satellite imagery. These include:

Satellite Operations Control Center (SOCC): This facility is responsible for controlling the Landsat satellites, monitoring their health, and ensuring they are functioning correctly. SOCC is located at the Goddard Space Flight Center in Maryland, USA.

Ground Data System (GDS): The GDS receives the data transmitted by the Landsat satellites and processes it into usable imagery products. The GDS is responsible for archiving Landsat data, generating products, and distributing data to users.

Landsat Science Team: The Landsat Science Team is a group of scientists who advise the USGS on scientific and technical issues related to Landsat data. The team helps ensure that Landsat data is of the highest quality and meets the needs of the scientific community.

Landsat Ground Stations: There are several Landsat ground stations located around the world that receive data from the Landsat satellites. These ground stations are responsible for receiving, processing, and distributing Landsat data to users.

Landsat operations involve the coordination of these different components to ensure that the satellites are functioning correctly, the data is being received and processed efficiently, and the resulting imagery is of the highest quality. [23][22]

10. LANDSAT ROMANIA

Landsat data has been used extensively in Romania for a variety of applications, including land cover and land use mapping, agriculture, forestry, geology, and hydrology. One example of Landsat's use in Romania is in monitoring land cover change. Landsat data has been used to study changes in land use and land cover in the country, such as the expansion of urban areas, deforestation, and changes in agricultural practices.

This data has also been used to study the effects of climate change on vegetation dynamics and agricultural productivity. Researchers have usedLandsat data to study the response of vegetation to changes in temperature and precipitation patterns, and how these changes may affect crop yields and agricultural productivity. In addition, acquired data has been used to study water resources in Romania, including surface water and groundwater. Researchers have used Landsat data to map and monitor changes in the country's river systems, as well as to study the impacts of climate change and land use on water resources.

Past couple of years this data has played an important role in understanding and managing natural resources in Romania, and has and will be used by local authorities and researchers, to make informed decisions about land use, water management, and environmental protection. [20][21]

11. LANDSAT 8 AN 9 OVER ROMANIA

In the past few decades, Romania's countryside has undergone significant changes in response to evolving land management policies and alterations in the natural environment. Consequently, numerous farms now exhibit a fascinating range of shapes and sizes, particularly when observed from an aerial perspective.

FIG.1 Acquired April 8, 2020[36]

These images of the Oltenia province in southwest Romania were captured by the Operational Land Imager (OLI) on Landsat 8 on April 8, 2020. The false-color representation of the images using bands 6-5-2 enhances the differentiation of various land covers across the province's mountains, foothills, and plains.

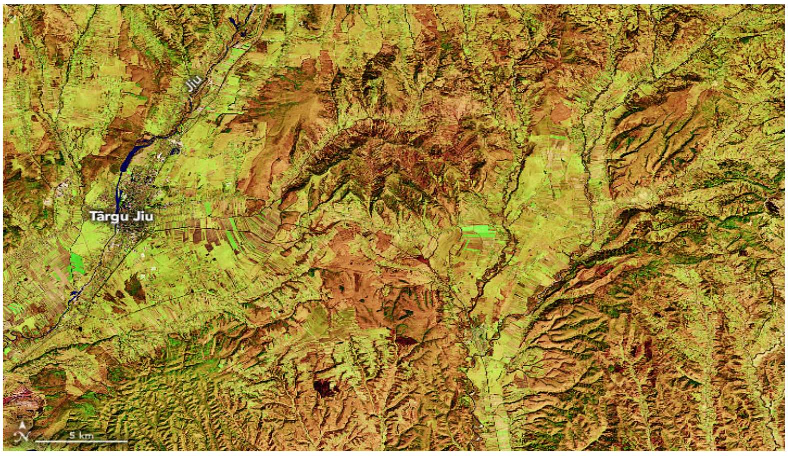

FIG.2 Acquired April 8, 2020 [36]

The top image provides a comprehensive view of the Oltenia province, encompassing the Olt River to the east, the Danube River to the south, and the South Carpathian Mountains to the north. The higher elevations of the Carpathian range, which surpass 2500 meters (8200 feet), are covered in snow and ice, depicted in light blue. The forested regions of the Carpathians, characterized by a mix of coniferous and deciduous trees, appear as a blend of dark green and orange colors.

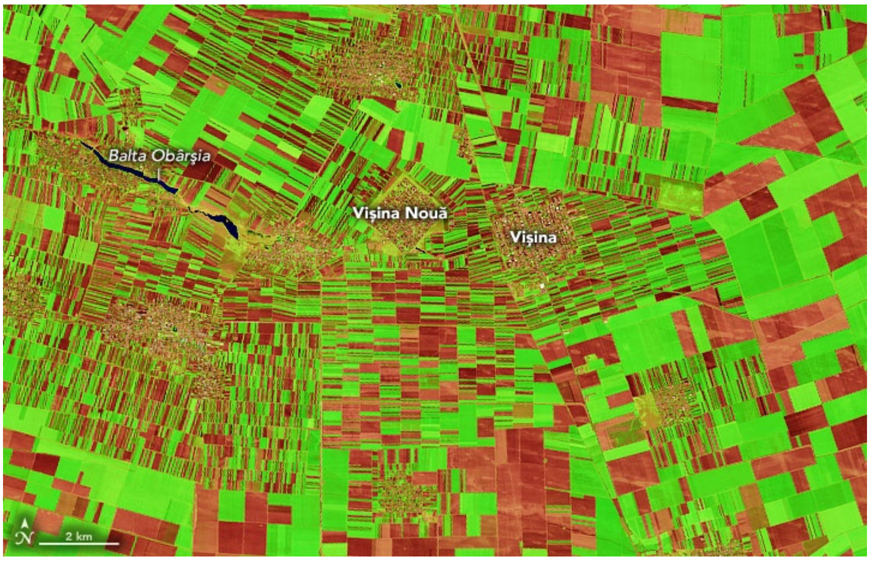

FIG.3 Acquired April 9, 2020 [36]

The lower elevations, ranging between 300 to 800 meters, exhibit forested areas (mostly orange) primarily consisting of oak and beech trees, spreading across the foothills. The valleys within the foothills display a vibrant green color, indicating thriving crops. The flat terrain adjacent to the river channels offers suitable land for farming amidst the otherwise mountainous terrain. [17][18][19]

12. LANDSAT AS A REMOTE SENSING TOOL

Landsat is a remote sensing program that uses satellites to capture images of the Earth's land surfaces. The Landsat satellites have a number of instruments on board, including the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS), which capture images in visible, near-infrared, short-wave infrared, and thermal infrared wavelengths. These images are used to study the Earth's land surfaces and the changes that occur over time.The imagery can be used to detect changes in land use, such as deforestation, urbanization, and agricultural expansion. It can also be used to monitor natural disasters, such as wildfires, floods, and landslides.

To analyze Landsat remote sensing data, a number of image processing techniques are used, such as image enhancement, image classification, and change detection. These techniques allow researchers to extract information from the images, such as the location and extent of different land cover types, and changes in land cover over time. The program provides a valuable resource for monitoring and understanding the Earth's land surfaces, and the remote sensing data it provides is widely used by researchers, policymakers, and natural resource managers around the world.

Limits and drawbacks: It is important to note that image sensing is just one tool in a larger toolbox of biometeorological methods. While image sensing can provide valuable data on vegetation cover, land use, and other biophysical features, it has limitations that must be addressed in order to make accurate and useful predictions and assessments.

One key limitation is the weather dependency of image sensing. Cloudy or rainy weather can reduce image quality or prevent image capture altogether, making it difficult to gather comprehensive data on a particular area. This limitation can be mitigated by using multiple sensors or integrating other data sources such as weather data, to ensure that missing image data is accounted for. Another limitation is the limited spatial coverage of image sensing. This limitation can be addressed by using satellite-based sensors or unmanned aerial vehicles (UAVs) to obtain data from larger or remote areas. However, these technologies can be expensive and require specialized expertise and equipment.

Temporal resolution is also a limitation of image sensing, as images are typically captured at discrete intervals, which may not capture the rapid changes in weather patterns or biophysical features that occur over short periods of time. To address this limitation, more frequent image capture can be used, or data from other sources, such as remote sensing or weather stations, can be used to supplement image data.

The high costs associated with image sensing can also be a barrier to its use in biometeorology, particularly in developing countries or regions with limited resources. To address this, alternative data sources and methods may need to be used, such as participatory methods or community-based monitoring, which can be more cost-effective and provide valuable data on local conditions.

Finally, the limited spectral resolution of image sensing can also be a limitation, particularly when attempting to differentiate between different biophysical features or patterns. This limitation can be addressed by using sensors with higher spectral resolution, or by combining image data with other types of data, such as meteorological or ground-based data, to provide a more comprehensive understanding of environmental conditions.

As a conclusion, while image sensing is a valuable tool in biometeorology, its limitations must be carefully considered when planning and implementing biometeorological studies. Alternative data sources and methods may need to be used to supplement image sensing data in order to obtain a comprehensive understanding of the impact of weather and climate patterns on living organisms and the environment. [15][16]

REFERENCES

[1] P. S. Thenkabail, (2019). *Remote Sensing in Agriculture: An Introduction*. Taylor & Francis;
[2] J. L. Hatfield & J. H. Prueger, (2015). *Handbook of agricultural meteorology*. Routledge;
[3] S. J. Goetz, A. G. Bunn, G. J. Fiske & R. A. Houghton (2005) *Satellite-observed photosynthetic trends across boreal North America associated with climate and fire distur*, of the American Meteorological Society, 78(4), 621-636;
[4] B. D. Wardlow, S. L. Egbert, J. H. Kastens & G. M. Henebry (2007). *Comparison of the growing season dynamics of NDVI and EVI for a Canadian prairie crop. Remote Sensing of Environment*, 107(2), 204-215;
[5] A. D. Richardson, J. P. Jenkins, B. H. Braswell, D. Y. Hollinger & S. V. Ollinger (2007). *Near-surface remote sensing of spatial and temporal variation in canopy phenology*, Ecological Applications, 17(6), 1919-1934;
[6] X. Xiong, J. Butler, Comprehensive Remote Sensing Volume 1, 2018, Pages 1-6, *Comprehensive Remote Sensing*;
[7] T. M. Lillesand, R. W. Kiefer & J. W. Chipman, (2015), *Remote sensing and image interpretation*, John Wiley & Sons;
[8] D. Bălteanu et al. (2013), *Land Use and Crop Dynamics Related to Climate Change Signals During the Post-Communist period in the South Oltenia, Romania*, Proceedings of the Romanian Academy, 15 (3), 265–278;
[9] D. Dogaru, et al. (2019), *Drivers and Dynamics of Agricultural Land Fragmentation in the Western Part of the Romanian Plain*, Romanian Journal of Geography, 63 (2), 145–165;
[10]JPL Photojournal (2020, February 3) PIA23677: Gorj Province, Romania. Accessed April 29, 2020;
[11] S. Qiu, J. Liu, Y. Liu & Y. Zhang, (2019), *Application of remote sensing technology in land surface temperature research: Progress and prospect. Remote Sensing*, 11(8), 944;
[12] Y. Peng, L. Zhang & Z. Gao, (2021), *Advances in the application of remote sensing technology in biometeorology*, International Journal of Biometeorology, 65(6), 901-914;
[13] P. S. Thenkabail, (2016), *Land surface temperature (LST) estimation from Landsat 8 satellite: Example from the irrigated and rainfed cropping systems in the Arizona Sonoran Desert, USA. In Remote sensing of land use and land cover: Principles and applications* (pp. 75-99). CRC Press;
[14] M. K. Ridd, (1995), *Exploring a V-I-S (vegetation-impervious surface-soil) model for urban ecosystem analysis through remote sensing: comparative anatomy for cities*, International Journal of Remote Sensing, 16(12), 2165-2185;
[15] T. Kuemmerle et al. (2009), *Land use change in Southern Romania after the collapse of socialism*, Regional Environmental Change, 9 (1);
[16] NASA Earth Observatory images by Joshua Stevens, using Landsat data from the U.S. Geological Survey. Story by Kathryn Hansen with image interpretation by Dan Bălteanu/Romanian Academy;
[17] M.V. Birsan, A. Dumitrescu, (2014), *Romanian daily gridded climatic dataset* (1961-2013), National Meteorological Administration, Bucharest, Romania. https://doi.pangaea.de/10.1594/PANGAEA.833627;
[18] E. Mateescu, M. Smarandache, N. Jeler, V. Apostol, (2013), *Drought conditions and management strategies in Romania*. In D. Tsegai &Ardakanian (Eds.), Capacity Development to Support National Drought Management Policies for Eastern European Countries (pp.56-61);
[19] M. Radoane & R. Popescu, (2018), *Assessment of vegetation response to climate change using Landsat data in Romania*, Environmental Monitoring and Assessment, 190(2), 74;
[20] L. C. Dincă & R. S. Savastru, (2020), *The use of Landsat data in monitoring land use/land cover changes in Romania*, In Advances in Environmental Research (Vol. 75, pp. 73-87). Elsevier;
[21] F. M. Chmielewski & T. Rötzer (2001), *Response of tree phenology to climate change across Europe. Agricultural and Forest Meteorology*, 108(2), 101-112;
[22] R. Geiger, R. H. Aron & P. Todhunter, (2003), *The climate near the ground. Rowman& Littlefield*;
[23] S. K. Dash, S. R. Goward, R. O. Dubayah, and A. R. Michaelis, *Advances in Remote Sensing Applications in Biogeography and Biometeorology*, Geogr. Compass, vol. 3, no. 6, pp. 2209–2238, Nov. 2009;
[24] A. C. Comrie and J. W. Thornes, *Biometeorology for urban planning and building design*, in Applied Climatology: Principles and Practice, Routledge, 2007, pp. 305–335;

[25] J. Kleerekoper, E. Van Esch, and P. Salcedo, *How to make a city climate-proof, addressing the urban heat island effect*, Resour. Conserv. Recycl., vol. 64, pp. 30–38, Feb. 2012;
[26] El Kenawy, A. M., & Ouarda, T. B. M. J. (2014), *Remote sensing applications in meteorology and climatology. Remote Sensing*, 6(5), 4177-4180. doi: 10.3390/rs6054177;
[27] G. Jia , X. Liu, X. Li, & D. Zhuang, (2020), *Satellite remote sensing applications in biometeorology: A review. Remote Sensing*, 12(18), 2981. doi: 10.3390/rs12182981;
[28] W. P. Menzel, (2019), *Satellite meteorology and biometeorology: An overdue integration*, International Journal of Biometeorology, 63(5), 603-609. doi: 10.1007/s00484-019-01704-z;
[29] C. S. B. Grimmond,& T. R. Oke, (2002), *Urbanization and global environmental change: local effects of urban warming*, The Geographical Journal, 168(4), 293-297;
[30] S.Hajat & T. Kosatky, (2010), *Heat-related mortality: a review and exploration of heterogeneity*, Journal of Epidemiology and Community Health, 64(9), 753-760;
[31] N. Kántor & A. Kovács, (2019), *Thermal comfort and heat stress risk in urban open public spaces–A review of assessment methods and metrics. Sustainable Cities and Society*, 47, 101469;
[32] T. R. Oke, G. T. Johnson & D. G. Steyn, (2011), *Thermal environment of urban areas*, Wiley Interdisciplinary Reviews: Climate Change, 2(5), 657-663;
[33] M. Santamouris, (2014), *Urban climate, heat island and sustainability: a review of strategies*. Sustainability, 6(2), 826-855;
[34] J. Tan, Y. Zheng, X. Tang, C. Guo, L. Li, & G. Song, (2010), *The urban heat island and its impact on heat waves and human health in Shanghai*, International Journal of Biometeorology, 54(1), 75-84;
[35] https://landsat.visibleearth.nasa.gov/view.php?id=147400.