CLIMATE CHANGE INDICATORS IN PROTECTED AREAS FROM THE ARAD COUNTY

Roxana BOJARIU, **Liliana Florentina VELEA, Roxana Diana CICA**
National Meteorological Administration, Bucharest, Romania

Abstract
Arad County is situated at the cross-road of important national and international routes and has a significant industrial development. Also, its touristic potential is important due to the diverse relief consisting of low plains, hills and mountains. The Mures Floodplain Natural Park which is crossing the Arad County is the second river in Romania with respect to its length and hydrographic area after the Danube. Temperature-derived indicators are analyzed for the area of the using in situ and satellite observations to detect trends which could affect the ecosystem dynamics. An upward trend in daily minimum air temperature was observed at Arad station for summer seasons during the period 1973-2012. In this case, the temperature increase was 2.2° C for the whole time interval. A similar behavior was found for minimum daily values of soil surface temperature at Arad (an increase of about 3.7° C in the interval 1973-2012) as well as for nighttime land surface temperature in the Mures Floodplain Natural Park derived from satellite observations (an increase of about 1° C in the interval 2002-2010). These changes have the potential to impact ecosystem dynamics in the Mures Floodplain Natural Park.

Keywords: climate change, protected areas, satellite data, ecosystem dynamics

Introduction

The Mures Floodplain Natural Park (or the Mures Meadow Natural Park) is the largest protected area from Arad County. The Natural Park is located in Arad and Timis counties starting outside the city of Arad and following the Mureş River up to the Hungarian border (figure 1). The park is a typical wetland ecosystem with rivers and lakes, alluvial forests, galleries of willows and poplars and water meadows covering 17,455 ha. The Inferior Floodplain of Mureş is bordered by dams and high terraces so floods often occur in this area adding nutrients and organic matter to soils. In addition, the land slowly absorbs the water from floods. All these features are of paramount importance for the specific ecosystem dynamics.

In the the Mures Floodplain Natural Park we can find a high biodiversity and a large number of species protected by international treaties and agreements and national laws. Plants are represented by over 1,000 woody and herbaceous species and subspecies. Grassland plains are made up of associations of Festuca, Poa, Lolium, Agrostis, Trifolium, Euphorbia, Plantago. (Administratia Parcului Natural Lunca Muresului, 2011).

Mammals species are represented by: deer (Cervus elaphus), wildbore (Sus scrofa), foxes (Vulpes vulpes), otter (Lutra lutra), evening bat (Nyctalus noctula), sides of hazel (Muscardinius avelanarius), ground squirrels (Spermophylus cytelus). Also, there are over 200 species of birds such as: spotted eagle (Aquila pomarina), Roller (Coracias garrulus), small duck (Anas querquedula), black stork (Ciconia nigra), Grey Heron (Ardea cinerea), little egret (Egretta garzetta), martin (Riparia Riparia), bee eaters (Merops apiaster), skylark (Alauda arvensis), eagle (Haliaeetus albicilla), Song Thrush (Turdus philomenes). A rich ichthyofauna consists of 50 species of fish such as: catfish (Silurus glanis), Acipenser ruthenus, Cobitis taenia, Gymnocephalus schraetzer, Misgurnus fossilis (Administratia Parcului Natural Lunca Muresului, 2011).

The Mures Floodplain was designated as a natural park by the Romanian government in 2005. Since 2006 the protected area "Mures Meadow" is the fourth Ramsar area in Romania. The Park was included in the List of Wetlands of International Importance. From 2008, the Mures Floodplain Natural Park is also part of Natura 2000 network, as a site of Community importance to protect 30 species and 12 habitats, and as a Special Bird Protection Area to protect the 41 species of birds (Administratia Parcului Natural Lunca Muresului, 2011). There are four strictly protected areas within the Mureş Flodplain Natural Park: Prundul Mare (717.9 ha), The Cenad Forest (310.5 ha), The Cenad Big Isle (2.1 ha), The Igriş Isles (7.0 ha). These areas have a more restrictive system of protection which prohibits activities of harvesting natural resources (Administratia Parcului Natural Lunca Muresului, 2011). In this study we will focus on thermal features of the Mures Floodplain Natural Park which are important for ecosystem dynamics in the climate change perspective. We analyze summers due to the fact that ecosystem dynamics is highly active at this particular time of the year.

1. Literature review

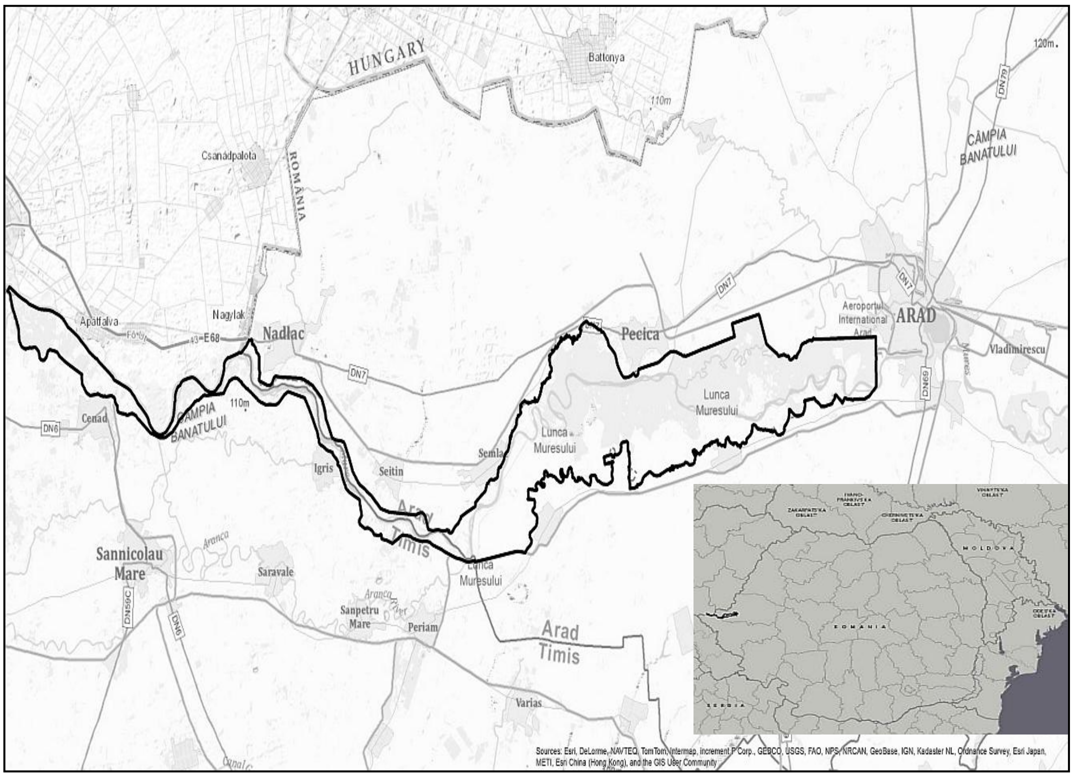
The study of Staiculescu (2012) provides a GIS-based framework for monitoring biodiversity in several Romanian protected areas, including the Mures Floodplain Natural Park. The GIS based integrated monitoring system is implemented according to the INSPIRE data specifications (http://inspire.jrc.ec.europa.eu). We think that a climate variability and change component could add value to the proposed system and our goal here to make a contribution in this regard. Also, the integrated data base for biodiversity is important for further impact study which couple climate to ecosystem dynamics.

2. Data

We used in this study temperature of land surface from the Moderate Resolution Imaging Spectroradiometer on NASA's Aqua satellite (Aqua MODIS) and in situ measurements at the Arad weather station. MODIS is an instrument aboard the Terra and Aqua satellites. Terra's orbit around the Earth passes over the equator from north to south in the morning, while Aqua passes from south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. The land surface temperature (LST) from the MODIS products is the radiometric temperature derived from the thermal infrared radiation emitted by the land surface, and measured instantaneously (Wan and Li, 2011). However, the "surface" in this case is whatever satellite detects throughout the atmosphere: grass, roofs of buildings, or leaves in the canopy of a forest. Thus, LST is not the same as the air temperature (Tair) that is measured at weather station even though they are somehow correlated. In our study, satellite observations of LST spatial pattern of summer climate in the Mures Floodplain Natural Park. This information is presented for further use in impact studies related to ecosystem dynamics.

Observations at meteorological station in Arad span a longer time interval (1973-2012) than satellite data (2002-2010), allowing us to study climate variability and change. Air temperature (Tair) is measured 2 m above the ground level with sensors protected from radiation and adequately ventilated to globally ensure the intercomparability between measurements at weather stations (Karl et al., 2006). It is important to emphasis that although correlated with Tair, LST differs from Tair in its physical meaning, magnitude, and measurement techniques (Jin and Dickinson, 2010).

Figure 1. Location of the Mures Floodplain Natural Park (black line) in Arad and Timis counties and in Romania.



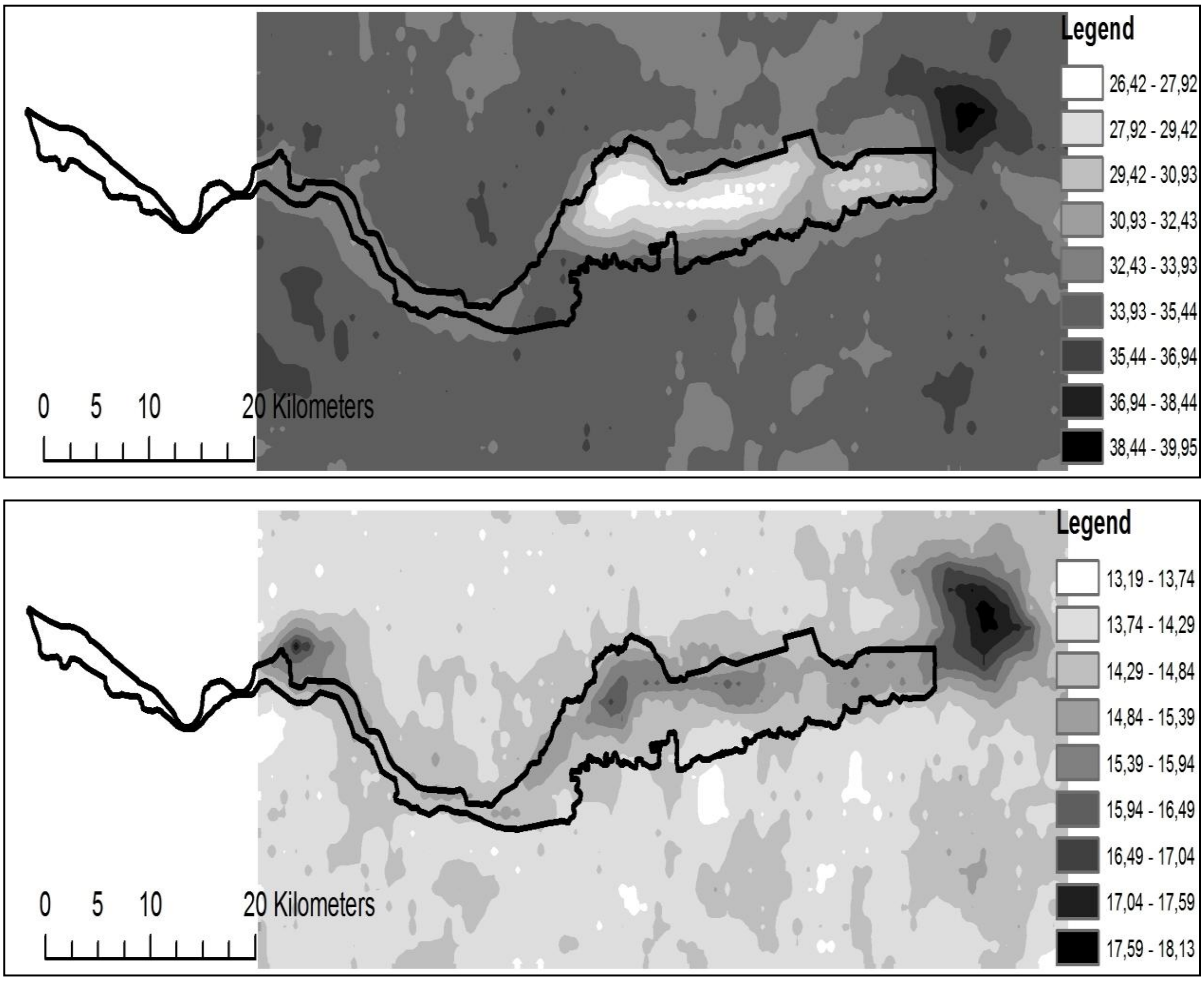
3. Multiannual summer climatology of land surface temperature

We used observations of LST at daytime and nighttime extracted from Aqua MODIS products to build a regular grid of multiannual averages covering the park area in the summers (June-August) from 2002 to 2010. The satellite-derived data at 1 km resolution are interpolated at 500 m resolution to draw the final map using the GIS software. Figure 2 presents these results.

The daytime map shows a strong thermal contrast between the forest-covered area in the Natural Park and the urban region of Arad municipality (figure 2). More than 12 degree Celsius is the maximum difference between surface temperatures in the two distinct areas. This is mainly due to evapotranspiration cooling and to the roughness of the forest enhancing cooling through turbulent exchange. Trees actively exchange absorbed solar radiation with the surrounding atmosphere and thereby maintain daytime canopy temperature close to the air temperature (Gates, 1965; Nemani et al., 1993; Waring, 2002). The large thermal difference between forest and urban areas captures the important distinction between canopy and urban heat island effects at daytime. In inner city, surface temperature is increased by heat trapping effect of high buildings, land surface covarage with materials characterized by high heat capacities, and the associated reduction in vegetation area and soil moisture content which usually reduce the surface temperature through evapotranspiration. Anthropogenic heat discharges due to energy consumption adds extra thermal stress in urban area.

The nighttime LST map illustrates a weaker thermal contrast between the inner city of Arad and the forest-covered area (figure 3). Forests have high surface roughness, which enables greater mixing and heat dissipation during the day, but may be a heat "trap" at nighttime (Lee et al., 2011). The urban skyline acts similar in this regard. Both daytime and nighttime maps clearly reveal the urban thermal island behavior of Arad municipality. A second urban heat island is visible in Nădlac location, at nighttime (figure 2, lower panel).

Figure 2. Mean land surface temperature (LST) (in ºC) derived from daytime (upper panel) and nighttime (lower panel) values of Aqua MODIS for June-August 2002-2010.



The satellite-derived maps of LST (figure 2) illustrate the unique role of forest-covered areas. This is primarily due to the fact that even during hot conditions when maximum temperatures occur, forests are able to access water for evapotranspiration with their deep root systems. A greater part of incoming solar radiation is then transformed into latent heat flux, thereby cooling the canopy surface temperature. Additionally, forests have deep, complex canopies that produce cooling through turbulent exchange. Forest areas sustain the hydrologic cycle through evapotranspiration which contributes to a cooling of climate through feedbacks with clouds and precipitation (Bonan, 2008). Deforestation will result in a higher LST, with significant impacts on the surface energy balance and hydrologic cycle of the affected area.

The shape of Mures Floodplain is clearly revealed in both daytime and nighttime maps, LST having lower, respectively higher, values than the nearby regions. During the day, the Sun's radiation warms lands. At night, the lands typically cool off because they release their warmth to air above while they are no longer receiving sunlight. However, the intensity of warming and cooling depends on soil moisture content which is higher near the river bed compared with the grasslands and cultivated areas. Higher soil moisture content decreases the land temperature at daytime and increases it during night. The satellite-derived maps suggest the existence of a mean thermal difference of about 1 degree Celsius between meadows and grassland/cultivated areas (figure 2). These thermal differences suggest again the importance of land use for thermal patterns which in turn could have a great effect on ecosystem dynamics.

4. Climate variability and change

Nighttime values of satellite-derived land surface temperature (in ºC) averaged over a part of Mures Floodplain Natural Park (color-shaded area within the black contour from figure 2) reveal a positive trend for the summers from 2002 to 2010 (figure 3). The nighttime values of LST increased with about 1 ºC in this time interval. Similar averaged values of daytime LST show a downward trend (around 0.6 ºC for the same period). However, 9 years do not represent a sound climate sample to draw conclusions on trends. We check the trends of available soil surface temperatures at the weather station in Arad for summers from 1973 to 2012. The minimum daily value of soil surface temperature at Arad station shows a similar upward trend as the nighttime LST averaged over the Mures Floodplain Natural Park (figure 4). The daily value of minimum soil surface temperature increased with about 3.7 degrees C in the interval 1973-2012. The maximum daily soil temperature at Arad is available only from 2001 and it has no trend for the interval 2001-2012 (figure 4).

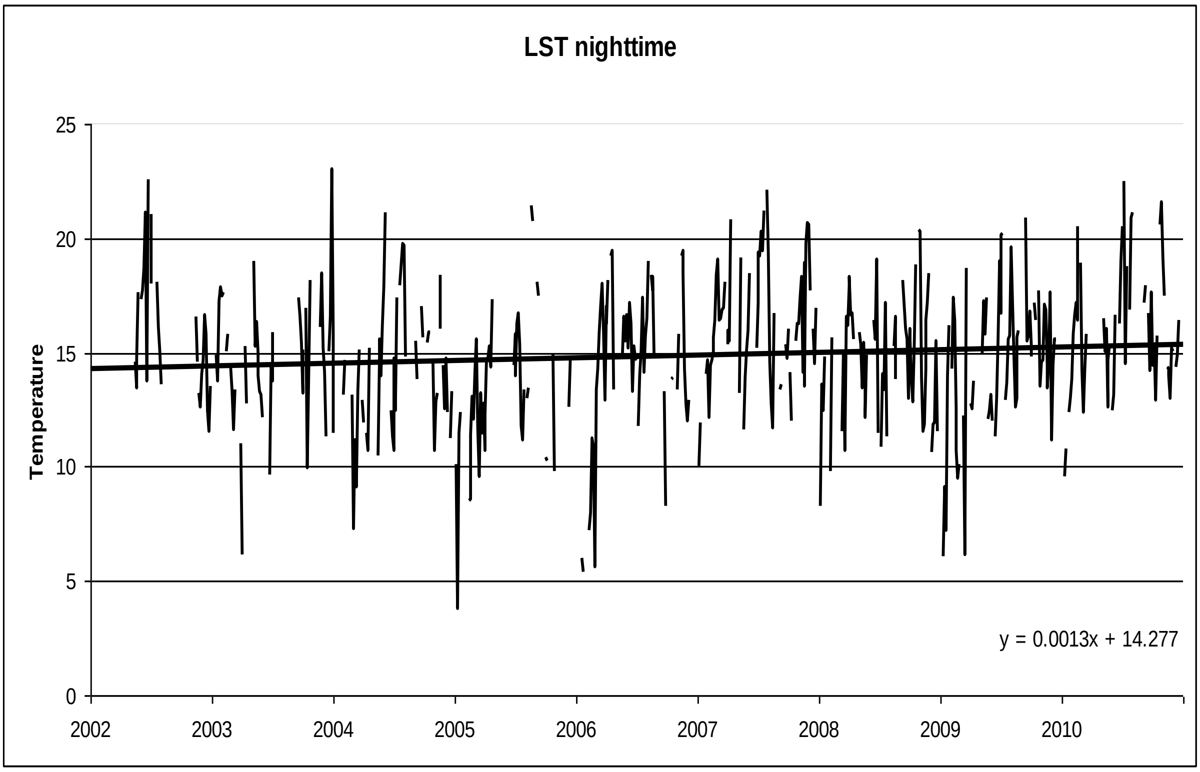
The day by day variability of maximum temperature of soil surface at Arad station is significantly higher than the variability of minimum temperature of soil surface. No such difference is in analyzed LST data, but we use spatial averages of LST and the averaging could mask the signal identified in the variability of observed data. As for air temperature in Arad, both minimum and maximum daily values show upward trends, the maximum temperature having a more pronounced increase (figure 5). In the interval 1973-2012 the increase in maximum daily temperature was about 3.7º C at Arad. Daily minimum temperature increased with about 2.2º C in the same period.

5. Conclusions and discussion

We analyzed available land surface temperature (LST) derived from the Moderate Resolution Imaging Spectroradiometer on NASA’s Aqua satellite. The nighttime values of LST averaged over the the Mures Floodplain Natural Park increased with about 1 ºC in the summers during the time interval 2002-2010. An upward trend with similar magnitude was found for minimum daily values of soil surface temperature measured at Arad weather station in the summers of the time interval 1973-2012. The increase in minimum daily values of soil surface temperature over the period 1973-2012 is 3.7 ºC. Upward trends of analyzed nighttime LST and minimum soil surface temperature are consistent with upwards trend of daily minimum air temperature observed at Arad station. Night LST is closer to minimum air temperature due to the lack of the solar radiation effect on the thermal infrared signal (Vancutsem et al., 2010). However, the analysis of daytime values of LST and maximum daily values of soil surface temperature from Arad station does not reveal any significant trend, even though the air temperature in the same location is significantly increasing. An explanation is that convection related processes add extra noise to daytime surface temperature compared with nighttime ones.

LST measures the canopy temperature in vegetated areas and could provide ecological information related to temperature-dependent physiological processes and associated energy fluxes. Satellite-derived LST have been used for a variety of applications including detection of ecosystem disturbance (Mildrexler et al., 2009; Coops et al., 2009), drought monitoring (Wan et al., 2004b), land cover monitoring (Julien and Sobrino, 2009), agrometeorology studies (Anderson et al., 2007), biodiversity studies (Albright et al.,2011), and have been proposed as an integrative global change indicator (Mildrexler et al., 2011).

Figure 3. Daytime and nighttime values of satellite-derived land surface temperature (in ºC) averaged over a part of Mures Floodplain Natural Park (color-shaded area within the black contour from figure 2). Satellite data are from Aqua MODIS (1 km resolution). Black lines represent the linear trends.



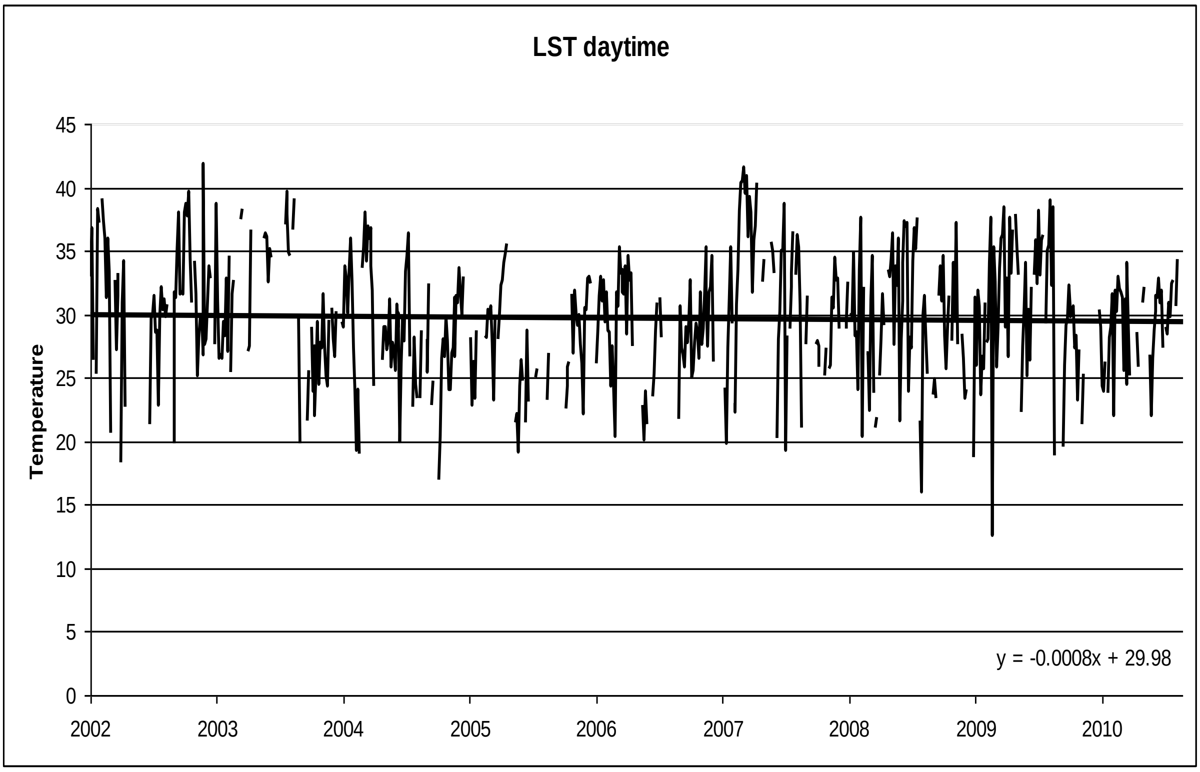


Figure 4. Daily values of maximum (blue line) and minimum (black line) soil surface temperature (in ºC) at the Arad weather station. The red line represents the linear trend

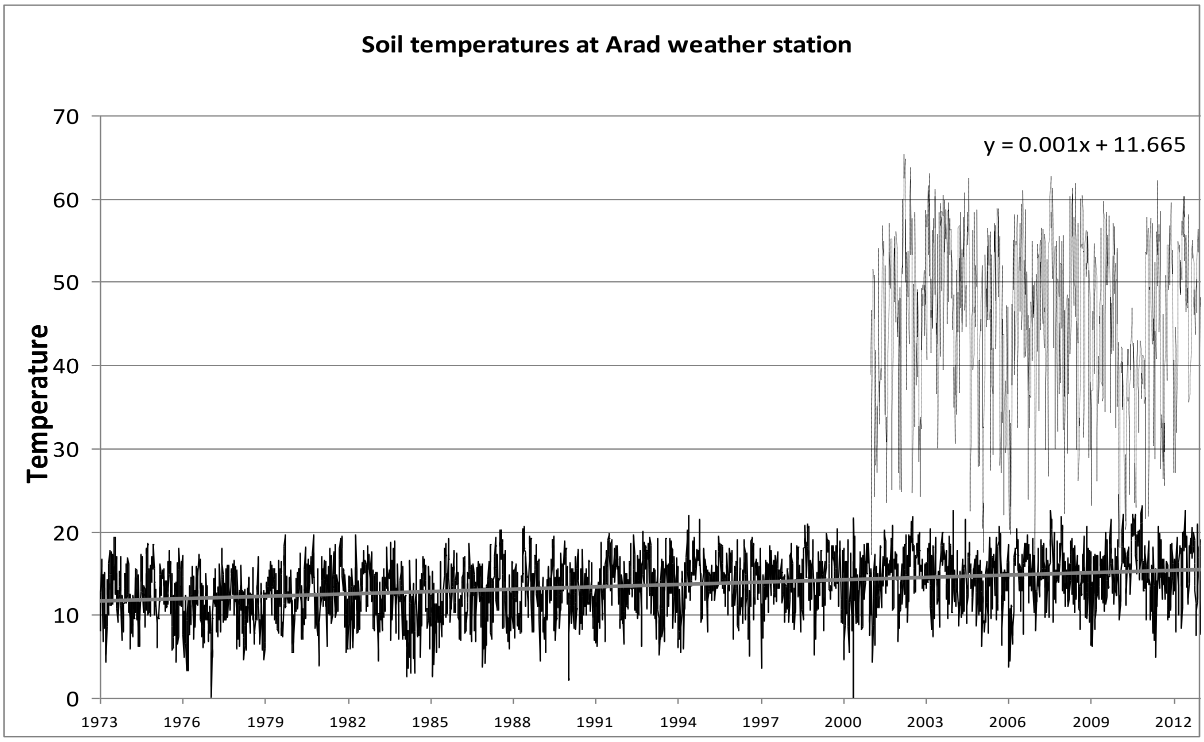
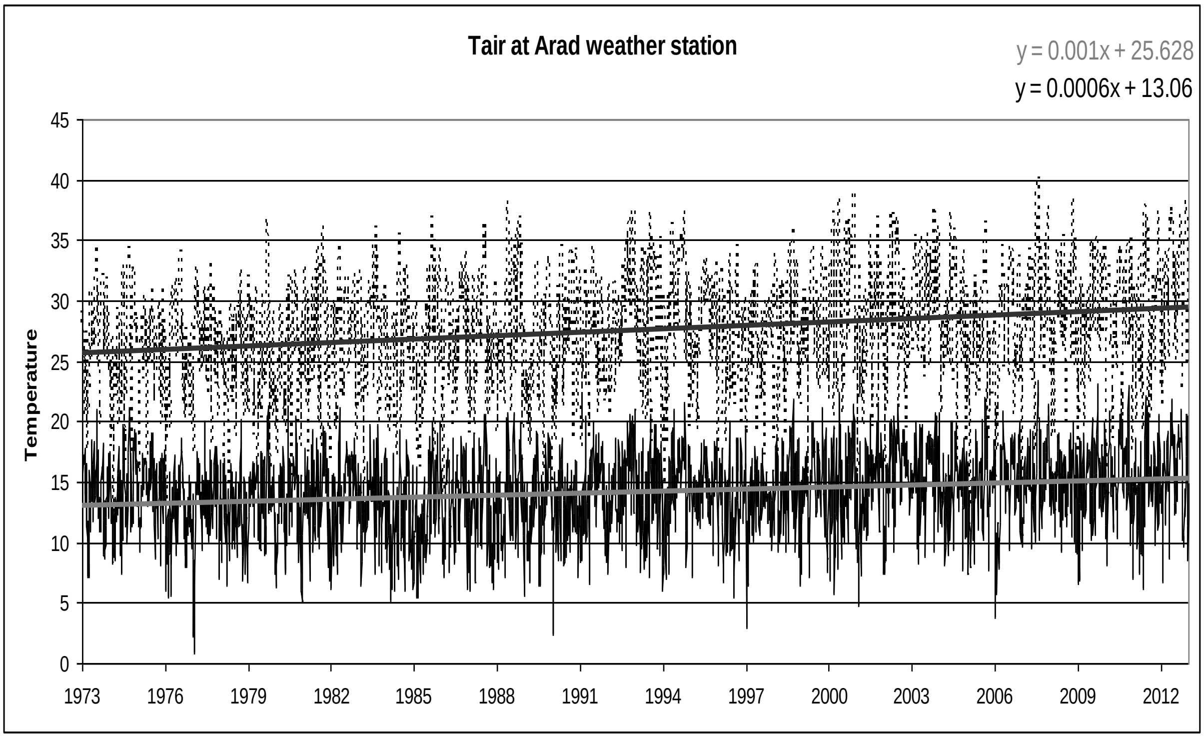


Figure 5. Daily values of maximum (red line) and minimum (blue line) air temperature (in ºC) at the Arad weather station for summers from 1973 to 2012. The gray lines represent the linear trends.



In addition, skin temperature can be used for monitoring vegetation water stress, assessing surface energy balance, detecting land surface disturbance, and monitoring condition suitability for insect–vector disease proliferation, among other uses (Pinheiro et al., 2006). Surface heat fluxes can induce local convection in the boundary layer, producing changes in air temperature, surface winds, cloudiness, and (potentially) precipitation (Aires et al., 2001).

Also, LST analysis could add information about the urban heat island influence on water quality. Hot pavement and rooftop surfaces transfer their excess heat to stormwater (Cool Pavement Report, 2005), which then drains into storm sewers and raises water temperatures as it is released into Mures river. Rapid temperature changes can be stressful to aquatic ecosystems in Natural Park.

Acknowledgement

This study was carried out in the frame of FP7 EURO4M-242093 project, with the financial support from European Commission.

References

Aires, F., C. Prigent, W. B. Rossow, and M. Rothstein, 2001, "A new neural network approach including first-guess for retrieval of atmospheric water vapor, cloud liquid water path, surface temperature and emissivities over land from satellite microwave observations", *J. Geophys. Res.*, 106: 14887-14907.

Albright, T. P., A. M. Pidgeon, C. D. Rittenhouse, M. K. Clayton, C. H. Flather, P. D. Culbert, and V. C. Radeloff ,2011, 'Heat waves measured with MODIS land surface temperature data predict changes in avian community structure', *Remote Sens. Environ*., 115: 245–254, doi:10.1016/j.rse.2010.08.024

Anderson, M. C., J. M. Norman, J. R. Mecikalski, J. A. Otkin, and W. P. Kustas, 2007, 'A climatological study of evapotranspiration and moisture stress across the continental United States based on thermal remote sensing: 2. Surface moisture climatology', *J. Geophys. Res*., 112, D11112, doi:10.1029/2006JD007507.

Bonan, G. B., 2008, "Forests and climate change: Forcings, feedbacks, and the climate benefits of forests", *Science*, 320: 1444–1449, doi:10.1126/science.1155121.

Coops, N. C., M. A. Wulder, and D. Iwanicka , 2009, "Large area monitoring with a MODIS-based Disturbance Index (DI) sensitive to annual seasonal variations", *Remote Sens. Environ*., 113: 1250–1261, doi:10.1016/j.rse.2009.02.015.

Gates, D. M., 1965," Energy, plants, and ecology', *Ecology*, 46: 1–13, doi:10.2307/1935252.

Jin, M. and R. E. Dickinson, 2010: 'Land Surface Skin Temperature Climatology: Benefitting from the Strengths of Satellite Observations, *Environ. Res. Lett*. 5 044004, doi:10.1088/1748-9326/5/4/044004.

Julien, Y., and J. A. Sobrino, 2009, "The Yearly Land Cover Dynamics (YLCD) method: An analysis of global vegetation from NDVI and LST parameters", *Remote Sens. Environ*., 113: 329–334, doi:10.1016/j.rse.2008.09.016.

Karl, T. R., C. D. Miller, and W. L. Murray, 2006, "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences", edited by T. R. Karl et al., U.S. Clim. Change Sci. Program and the Subcomm. on Global Change Res., Washington, D. C.

Lee, X., Goulden, M.L., Hollinger, D.Y., Barr, A., Black, T.A., Bohrer, G., et al., 2011. 'Observed increase in local cooling effect of deforestation at higher latitudes', *Nature,* 479: 384–387.

Mildrexler, D. J., M. Zhao, and S. W. Running, 2009, "Testing a MODIS global disturbance index across North America", *Remote Sens. Environ*., 113: 2103–2117, doi:10.1016/j.rse.2009.05.016.

Mildrexler, D. J., M. Zhao, and S. W. Running, 2011, "A global comparison between station air temperatures and MODIS land surface temperatures reveals the cooling role of forests", *J. Geophys. Res.*, 116, G03025, doi:10.1029/2010JG001486.

Nemani, R. R., L. L. Pierce, and S. W. Running, 1993, "Developing satellite derived estimates of surface moisture status", *J. Appl. Meteorol*., 32: 548–557, doi:10.1175/1520 0450(1993)032<0548:DSDEOS>2.0.CO;2.

Pinheiro, A.C.T. , Mahoney,R., Privette, J.L. and Tucker, C.J. , 2006, "Development of a daily long term record of NOAA-14 AVHRR land surface temperature over Africa", *Remote Sens. Environ*, 103: 153-164.

Staiculescu (Ipate) S., 2012, 'Application of GIS Technologies in Monitoring Biodiversity', *Geoinformatics Forum,* Salzburg, 485-494.

Vancutsem, C., P. Ceccato, T. Dinku and S. Connor, 2010, 'Evaluation of MODIS land surface temperature data to estimate air temperature in different ecosystems over Africa', *Remote Sensing of Environment*, 114 (2): 449 - 465. doi: x.doi.org/10.1016/j.rse.2009.10.002

Wan, Z., and Z. L. Li, 2011, "MODIS land surface temperature and emissivity", in *Land Remote Sensing and Global Environmental Change, Remote Sens. and Digital Image Proc*., vol. 11, edited by B. Ramachandran et al., pp. 563–577, Springer, New York.

Wan, Z., P. Wang, and Z. Li, 2004, 'Using MODIS Surface Temperature and Normalized Difference Vegetation Index products for monitoring drought in the southern Great Plains, USA', *Int. J. Remote Sens*., 25: 61–72.

Waring, R. H., 2002, "Temperate coniferous forests, in Encyclopedia of Global Environmental Change", vol. 2, John Wiley, Chichester, U. K.

*** "Cool Pavement Report". Environmental Protection Agency. June 2005. 21-43.

***Administratia Parcului Natural Lunca Muresului, 2011, Planul de management al al Parcului Natural Lunca Muresului, 187 pp.