The 3rd Annual Conference Global Change and Resilience
Brno, Czech Republic, May 22nd – 24th, 2013

Evapotranspiration fluxes across lowland mesoscale catchments in current and past climate conditions

Urszula Somorowska email: usomorow@uw.edu.pl
Mateusz Slazek email:mslazek@uw.edu.pl
University of Warsaw, Faculty of Geography and Regional Studies, Krakowskie Przedmiescie 30, 00-927 Warsaw, Poland

Introduction

Normalized Difference Vegetation Index (NDVI) is generally considered as a good indicator of terrestrial vegetation productivity and may be useful for the estimation of the evapotranspiration (ET) at a regional scale for a long-term hydrologic applications (e.g. Szilagyi et al. 1998). A number of applications are based on the relationship between the values of ET and NDVI relying on the positive slope of the two variables identified across different vegetation types.

In this study, the correlation between monthly values of ET and NDVI is investigated in years 2001-2012 to assess the possibility of reconstruction of ET from NDVI values in the last two decades of the 20th century. Correlations presented here in are investigated in two lowland mesoscale catchments of central Poland (Fig. 1). Catchment of the Liwiec river drains the area of 2471 km^2, whereas catchment of the Nurzec river – 2087 km^2, both with dominant agricultural land use. The main aim is to answer the question if the hydrological cycle is accelerating in terms of potential increase of evapotranspiration. Specifically, it is to detect if there is an increase of evapotranspiration and how much more of green water participates in hydrological cycle in a gradually warming climate.

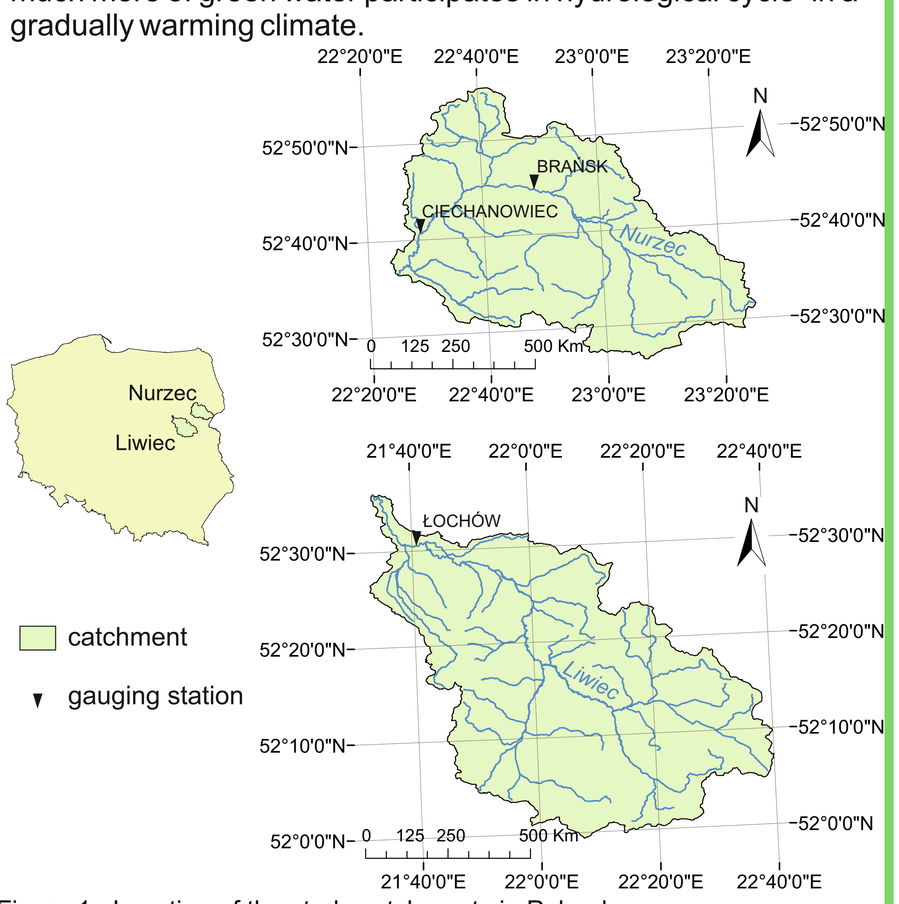

Figure 1. Location of the study catchments in Poland

Methods of analysis

Algorithm to estimate ET using the Penman-Montheith and high-resolution satellite images was developed by the Numerical Terradynamic Simulation Group at the University of Montana (Mu et al. 2007). Evapotranspiration estimates from the Moderate Resolution Imaging Spectroradiometer (MODIS) project were acquired at a spatial resolution of 1 km and temporal resolution of 1 month in years 2001-2012. The MODIS data product named 'MOD16A2' was acquired to extract the subdata set of the ET. Data were extracted and processed in the ArcGIS version 10.0 using horizontal tile number 19 and vertical tile number 03 (h19v03). In the analysis of the interaction between ET and vegetation, the Normalized Difference Vegetation Index (NDVI) was applied using the MODIS data product named '13A3' at the same spatial resolution of 1 km, selecting daily images from each month. Besides, the mean monthly NDVI values in historic period 1981-2000 were acquired from the NOAA Advanced Very High Resolution Radiometer (AVHRR) at the spatial resolution of 0.1° which in the analyzed catchments corresponds to the pixel resolution of approximately 5x5km. These NDVI data were extracted from the Global Data Archive 2 distributed by the Clark Labs (Clark University, US), in the IDRISI project. The data in the latitude/longitude IDRISI format, were re-projected here into the Polish Coordinate System (PUWG1992) in the ArcGIS 10.0. Spatial patterns of NDVI averages and ET sums in the summer half of the year (May-October) were correlated for the period 2001-2012 as a base for the reconstruction of the historic average values of the ET in the period 1981-2000. The linear regression analysis was applied to analyze NDVI-ET relation.

Evapotranspiration fluxes and regime transition

Figure 2 shows the spatial patterns of the mean NDVI values and ET sums in summer half of the year (May-October) for the period 2001-2012. High values of NDVI are related with high photosynthetic activity and good conditions of plants. Generally, the high values of ET correspond to high values of NDVI in both catchments which is mostly found in the areas adjacent to rivers. Here high groundwater levels ensure sufficient amount of water to rise from the soil matrix to the atmosphere. Much lower values are found in cropland. Relationship between NDVI and ET sums, based on the pixel values and averaged for the period 2001-2012, is displayed in figure 3. For NDVI-s equal to 0.8, the values of ET sum (May-October) reach the level of approximately 450 mm. However, the cloud of all points might be separated into two groups within which the coefficients of determination are much higher (0.82-0.86) than for the whole ensemble of pixels (0.44-0.46). Blue points concern the pixels located within low-lying areas or characterized by high soil retention capacity.

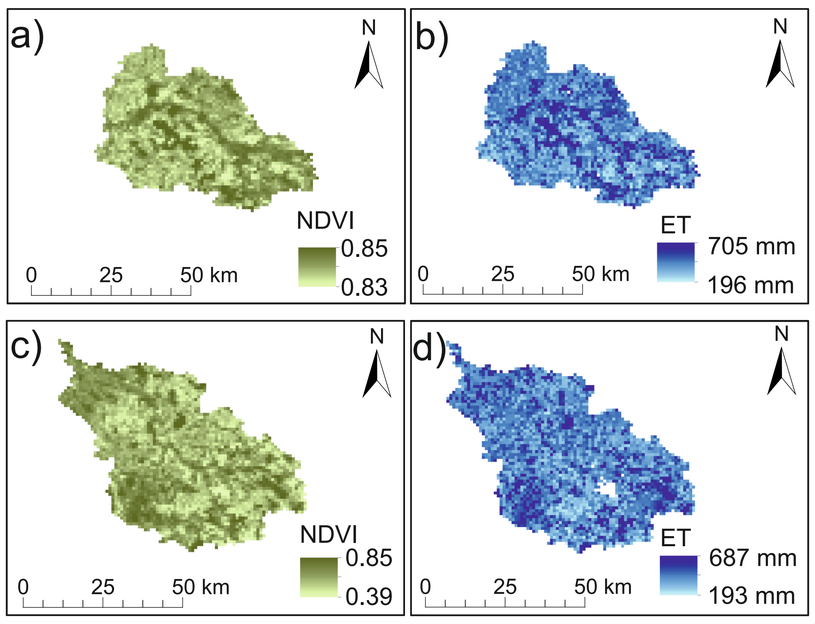

Figure 2. Spatial patterns of ET and NDVI as an average for the summer season (May-October) in years 2001-2012 in the Nurzec catchment (a, b) and in the Liwiec catchment c), d)

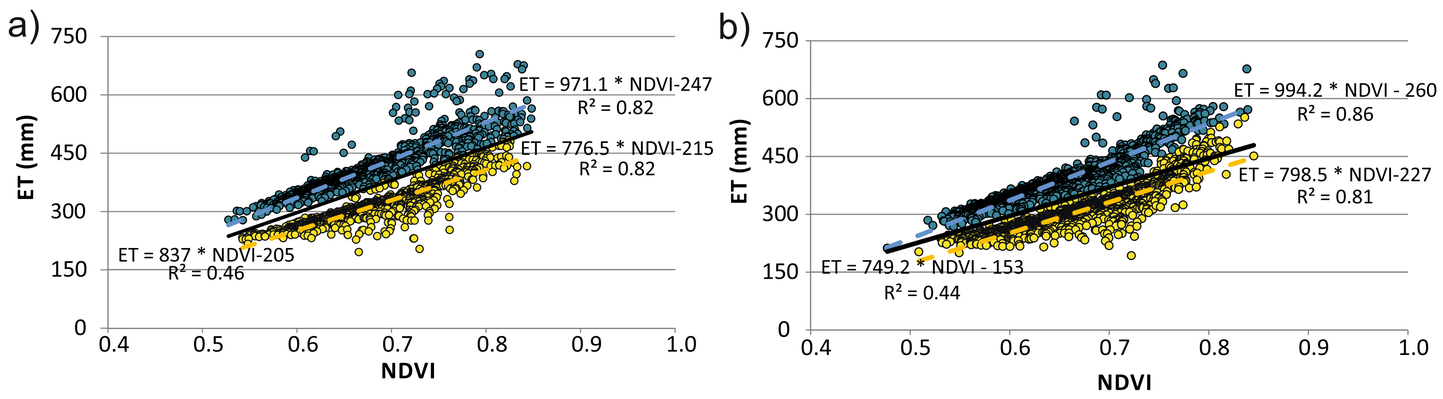

Figure 3. Values of ET sum versus NDVI averaged for the summer season (May-October) for the Nurzec catchment (a) and for the Liwiec catchment (b). Correlation based on the pixel values

Established linear regression equations were applied to reconstruct the value of ET from the NDVI on the average for summer half in years 1981-2000 (Fig. 4). Mean summer ET in years 1981-2000 was equal to 322 mm in the Liwiec catchment and 354 mm in the Nurzec catchment, whereas in years 2001-2012 these values were accordingly equal to 339 mm and 364 mm.

The resolution of historic NDVI images is much coarse than those from the last years but rough seasonal changes of ET might be derived (Fig. 5). Increased ET is observed mainly in months June and July as compared to those in the historic period, whereas decreased – in September and October.

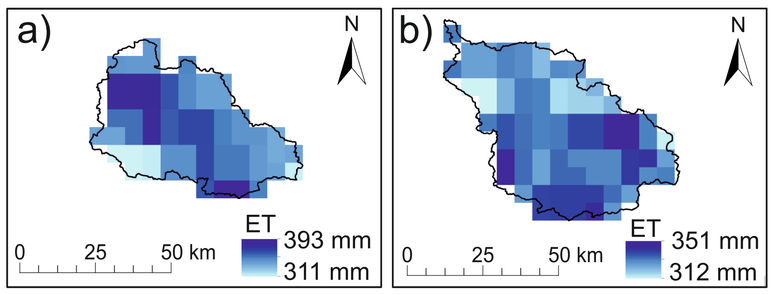

Figure 4. Mean monthly values of evapotranspiration reconstructed in the period 1981-2000 in the Nurzec catchment (a) and in the Liwiec catchment (b)

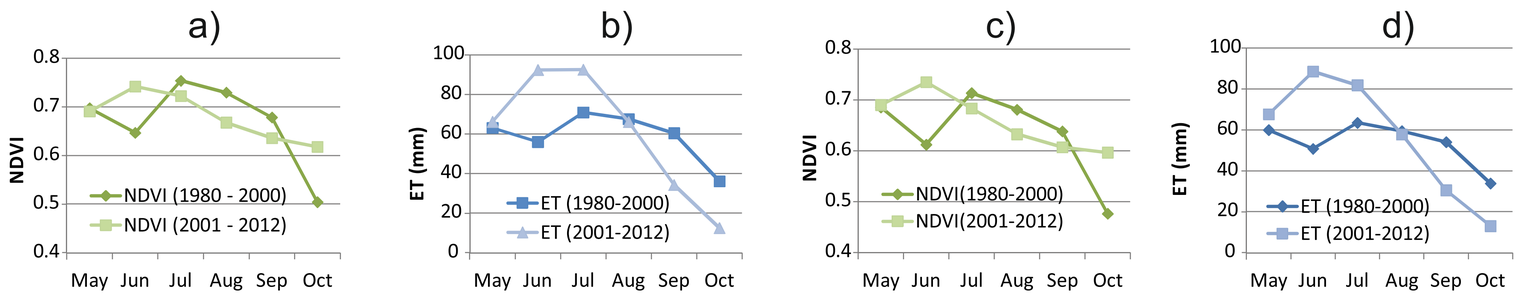

Figure 5. Mean monthly values of NDVI and evapotranspiration for two comparative periods in the Nurzec catchment (a, b) and in the Liwiec catchment (c,d)

Although the NDVI-ET linear relations were found to be statistically significant, the problem of reliable reconstruction of ET requires additional research including time-lag analysis between two variables and including the spatio-temporal patterns of other variables to explain characteristic pixel grouping.

References

Mu, Q., Heinsch, F.A., Zhao, M., Running, S.W. (2007). Development of a global evapotranspiration algorithm based on MODIS and global meteorology data. *Remote Sensing of Environment*, 111, 519-536.

Szilagyi, J., Rundquist, D. C., Gosselin, D. C. and Parlange M. B. (1998). NDVI relationship to monthly evaporation. *Geophysical Research Letters*, 25(10), 1753-1756.