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LOCAL CLIMATE DRIVERS DISTRIBUTION AND POINT MEASURED TEMPERATURES - A CASE STUDY IN POSTAVARU MOUNTAINS

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Abstract: *The paper presents several applications of the geographic information systems (GIS) in studying the spatial distribution of some primary and secondary terrain derivatives that act as important local climate drivers and an exploratory analysis of their reciprocal correlations and the relationships with point measured temperatures. Solar radiation enters the atmosphere system through the ground surface, that influences the climate by its reflective properties and shape that could be effectively analysed in GIS. Among terrain parameters, in the study area, aspect occurs to be strongly correlated with modelled incoming radiation and measured temperatures show a clear altitude effect, shaded under spruce canopies and disturbed on windy summits.*

Key words: *local climate, terrain derivatives, temperatures.*

1. Introduction

Climate conditions play a decisive role in environmental and biological processes [1], [8], [13]. Consequently, their accurate evaluation at the highest possible resolution is the utmost importance in complex geosystems modelling and biophysical processes simulation [3], [18].

In mountain regions, the spatial distribution of climate elements follows complex patterns, due to the influence of multiple factors [2], [4]. The local terrain conditions affect net radiation through aspect, slope, visible sky and hillshading and these are additionally influencing the heat balance, by inducing differences in soil properties (for example, in its humidity, dependent on water circulation by overland and subsurface flow) [17].

The local climate variability in mountain regions is brought into special focus by the present concern regarding the possible climate changes [11], [16]. The scenarios established at large-scale and regional level by using global and regional climate models require amendments in steep terrain areas, where for instance warming and drying trends could be enhanced on southern steep slopes and buffered on northern gently inclined areas [14], [15].

In forest areas, the structure of the stand canopy plays also an extremely important role, sometimes attenuating the terrain effects. For instance, the dense spruce canopy controls very efficiently the

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temperature regime beneath, reducing at a minimum the influence of some topographic factors, such as aspect, visible sky and others.

The geographic information systems (GIS) development and especially the possibility of accurately representing the land forms in the digital terrain models offer new possibilities for the topo-climatological studies. The paper briefly presents several GIS applications in studying the spatial distribution of some land morphometry parameters that act as important local climate drivers and an exploratory analysis of their reciprocal correlations and the relationships with point measured temperatures.

2. Material and methods

The study area is located in the Postavaru Mountains (Figure 1), situated near Brasov City, in south-eastern Transilvania, central Romania.

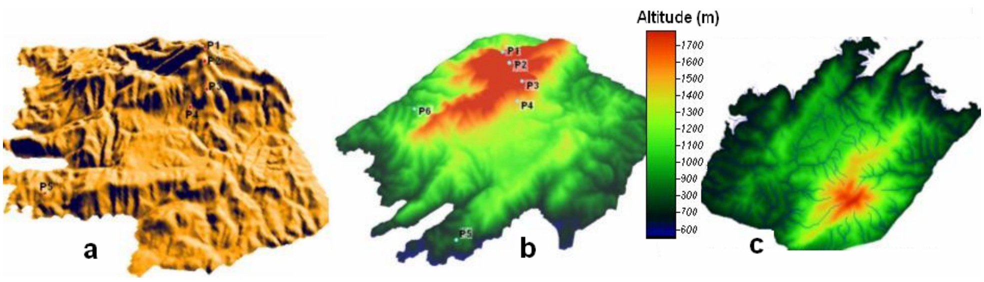

Fig. 1. *The study area: Postavaru Mountains in hillshaded three dimensional view (**a**), the elevation distribution (**b, c**) and the location of the temperature measurement points*

The digital terrain analysis was carried out by using the System for Automated Geoscientific Analyses (SAGA), an open source software, initially developed at Gottingen University (Germany) and then enriched by many contributors [6], [7].

As any other GIS software, beyond the possibilities for suggestive three dimensional views (as illustrated in Figures 1 and 2), SAGA provides powerful spatial analysis tools, including modules for calculating layers of primary land parameters, such as the "classical" slope and aspect (Figure 2) and secondary terrain derivatives, that act as important local climate drivers, like visible sky, potential incoming radiation, with the direct beam and diffuse components etc. (see § 3).

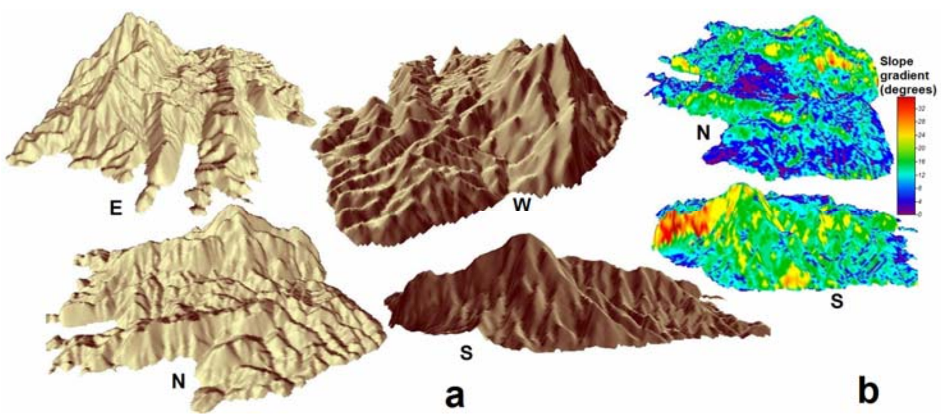

Fig. 2. *Slope aspect (**a**) and gradient (**b**) in the study area, in three dimensional views, from different cardinal points (**E, W, N** and **S** for aspect; **N** and **S** for slope)*

The modern automatic measurement devices (sensors, sensor-loggers etc.), enable a new approach in the study of local climate conditions spatial variability. The point measured temperatures used for comparisons in the present paper were obtained by using temperature and relative humidity sensor loggers (Hobo Pro v2, U23-001), installed in the field, in different terrain and cover contexts (see Figure 1 for the position of the measurement points). Five of the selected sensor loggers (P1 to P5) were installed in comparable cover conditions (shaded but well ventilated positions) enabling the analysis of the terrain influence and one (P6) is located in a dense spruce stand, for pinpointing the overwhelming effect of such forest cover, "shading" the land forms` effects.

3. Results and Discussions

Among the climate elements, air temperature represents a parameter of vital importance for the accurate description of the local conditions [5], [9], thus the spatial variation analysis of its terrain drivers is the topic on which this study is mainly focused.

In steep terrain areas, a parameter widely considered for projecting the local climate differentiations, of air temperature in particular, is altitude or elevation. Its distribution over the study area, represented by the digital elevation model (DEM), which can be observed in Figure 1, offers a basis for calculating, for instance, arrays of adjusted temperatures by taking in account the average environmental lapse rate ($6^{o}C/km$).

But in this way, only one variation component is considered, namely the advection one, which brings on the mountain slopes colder air from the same level in the surrounding free atmosphere. The second component to be considered should be the local input of solar radiation, which represents the main climate genetic factor and has a direct influence on the heat balance of a land element (in addition to its indirect influence, through the environmental lapse rate, determined by major solar radiation absorption at ground level, that thus represents the mean heat source of the atmosphere).

As regards the distribution of the radiant energy, this could be established by calculating the incidence angle of the sun rays and the visible sky for each position (cell in the GIS raster model) of the study area, the latter influencing both the diffuse radiation amount and the sunshine duration in clear sky days [10].

The visible sky layer (in percents, or the corresponding subunit values, known as sky view factors), shown in Figure 3, occupies a central position in analysing the diffuse radiation distribution that was proven to be strongly related with the soil and air temperature [12], [18], [19].

In the classical approach, prior to the development of the geographic information systems, slope aspect and inclination in particular sites were generally used for estimating the differences in solar energy input (radiation proxies) and presently their easy and quick GIS determination (Figure 2), as primary terrain derivatives, keeps them widely used in topo-climatology studies.

In the study area, the visible sky factors occur to be independent of aspect and significantly correlated with slope (0.72, 97.3% confidence), as a consequence of the steeper slopes concentration in the massif upper areas (Figure 3).

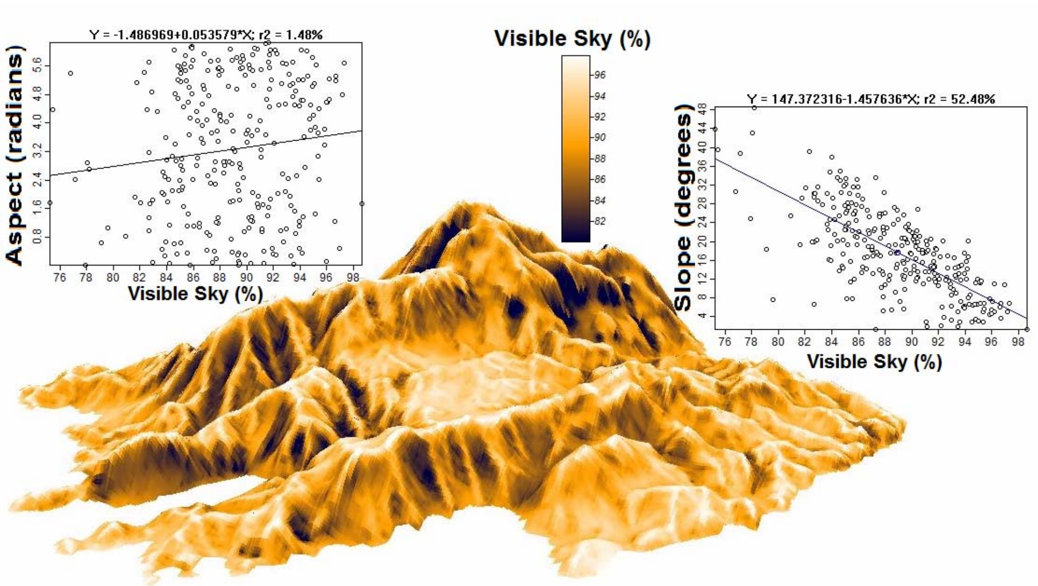

Fig. 3. *Visible sky (%) distribution in the study area and its relations with aspect (radians) and slope (degrees)*

SAGA provides modules for solar input calculations, that were used for calculating the hourly values (at 1 pm) of direct beam, diffuse and total incoming radiation, daily totals and sunshine durations for two August days (19th and 25th), as illustrated in some example charts in Figure 4.

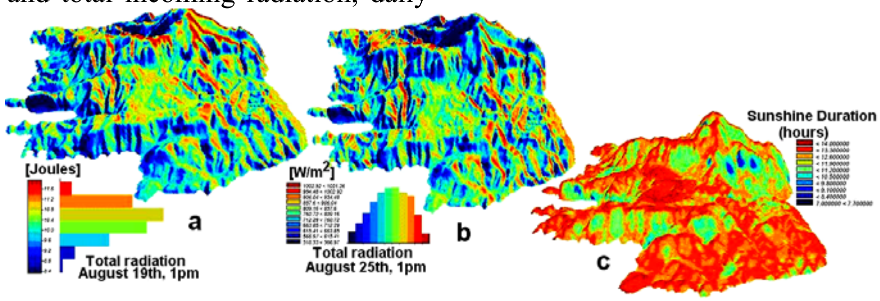

Fig. 4. *Total incoming radiation on August 19th, 1p.m. (**a**), August 25th, 1p.m. (**b**) and sunshine duration, August 19th (**c**)*

The relationships between the solar radiation parameters (for August 19th, 1p.m.) and raster cell aspect and slope could be studied on the Figure 5a graphs. One could easily observe the expected correlation between aspect, total and direct radiation. As slope increases, the values scattering decreases for diffuse radiation, but increases for the sun beam component, and subsequently for the total short wave input.

As regards the SAGA default module for calculating land surface temperature, the results obtained (considering a dummy constant leaf area value) show no significant correlation with the incoming radiation but a perfect one with altitude (Figure 5b) that demonstrates the exclusive modelled influence of the mean lapse rate.

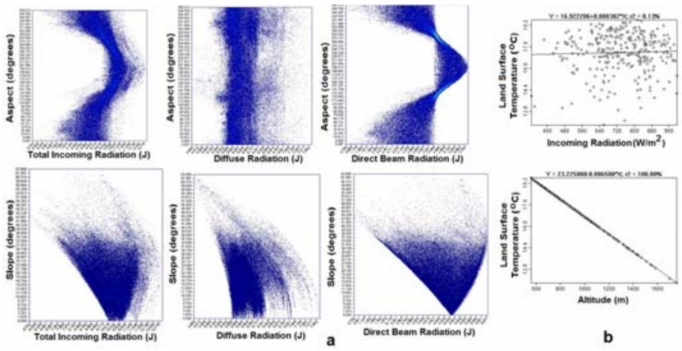

Fig.5. *Relationships between:* ***a****- August 19th (1p.m.) total, diffuse and direct beam radiation, aspect, slope,* ***b****- modelled surface temperature, incoming radiation, altitude*

The various layers with terrain and solar radiation parameters were used for extracting the point values for the positions of the sensor loggers, in order to enable the analysis of their relationships with the measured temperatures, at 1 pm, in a summer clear sky (August 19th, 2014) and an overcast day (August 25th, 2014).

As one could observe in Figure 6a, the temperature values, in the two days, seem to be well related in four points, with outliers as expected in the stand spruce (P6) but also on the summit (P1), where the clear sky value is almost as high as the one measured 1000 m below (P5). This peculiar behaviour of temperature in points P1 and P6 is also obvious in the other charts of Figure 6 (b and c), where along with the six points temperature profiles are those of altitude (m) respectively visible sky (%). When taking into account all 6 points, there are no correlations (as also a glance on the graphs would suggest) but the situation changes when the outliers are removed. Thus by taking into account only three points (3, 4, 5) the correlations with altitude are significant in both the clear sky day (-0.99, 97.51% confidence even for this extremely small sample) and the overcast one (-0.99, 99.26% confidence).

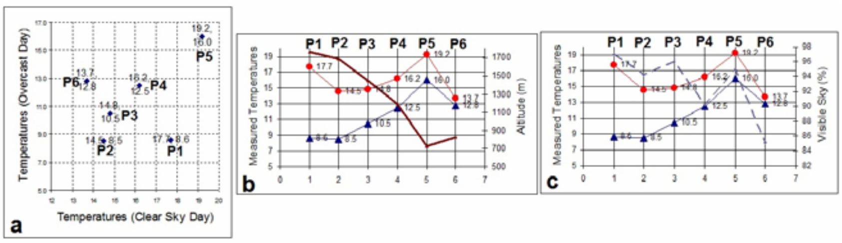

Fig. 6. *Relationships between measured temperatures (****a****) in a clear sky (August 19th, 2014) and an overcast day (August 25th, 2014), with altitude (****b****) and visible sky (****c****)*

4. Conclusions

Solar radiation enters the atmosphere system through the ground surface, which influences the climate by its reflective properties and shape (landforms) that could be effectively analysed in GIS. Among terrain parameters, aspect seems to be strongly correlated with the modelled incoming radiation, and the measured temperatures show a clear altitude effect, shaded under spruce canopies and disturbed on windy summits.

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