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THE IMPACT OF RELIEF AND LAND USE ON THE DIVERSITY OF LOCAL CLIMATE

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Abstract

This article discusses the impact of relief and land usage on the principle characteristics of local climate - air temperature. Research has been conducted in the Garlica Murowana village, situated in the southern part of the Krakowsko-Częstochowska Plateau. This particular village can be characterized by abundant terrain relief and diversified utilization. Temperature measurements have been carried out in the years 2006-2009 in series that lasted several weeks each. The localization of instrument shelters featured upland forms, valley and slopes with southern, western and northern expositions, as well as various arable land such as cultivated fields, built-up area, forest and meadow. The climatic diversification at local scale is more pronounced in radiation type weather, which is characteristic of high pressure synoptic situations. Therefore, the analysis of temperature course has been performed for selected synoptic situations.
This research indicated that the most favourable areas in terms of thermal conditions are represented by southern and western slopes, as well as upland terrain, whilst the valley is characterized by occurrence of highest maximum temperatures and diurnal temperature amplitudes (temperature inversions). The most evident, and statistically significant characteristic is the impact of relief and land usage on the dynamic changes of air temperature. It should be noted that this occurs during the warm season (summer and early autumn). During autumn and winter the impact of relief and land usage is notably smaller.

Key words: local climate, topoclimate, relief, land use

Introduction

Air temperature on areas with varied terrain relief and various means of utilization is modified by settlement factors and local circulation. In a landscape which is susceptible to anthropogenic transformation, changes in land use lead to changes of climatic elements, and vice versa climate change conditions land utilization (Yoshino 1975, 1997). In suburban areas changes in land use occur at a fast pace. They consist mainly of exclusion of soils from agricultural usage, and destining them for built up areas. Due to changing terrain functions, the individual characteristics of active layer change as well. During the summer season built-up areas warm much faster, and temperatures are significantly higher than on agricultural lands or frest terrain (Wojkowski 2004).

One of the climatic elements that are used to describe local climate is the daily course o air temperature. The greatest diversity of meteorological conditions, which results from the interaction of relief, vegetation and soils, occurs in radiation type weather, characterized by insignificant cloud cover, and light winds, which are common for high-pressure weather

systems (Mucha 2004; Nowosad 2000; Niedźwiedź 1973, 2003, Obrebska–Starklowa at al. 2003; Paszyński at al. 1999). Hence the selection of described days has been conditioned primarily by weather types that predominate in the Upper Vistula basin.
In cloudy and windy weather characteristic for low-pressure system, the course of meteorological elements (air temperature and humidity) predetermined by local factors, become fuzzy (Bokwa 2010, Olechnowicz-Bobrowska, Ząbczyńska 2001).
The main goal of this article is to determine the impact of relief and land usage on the diversity of thermal conditions during high-pressure synoptic situations based on the example from Garlica Murowana. This particular village is situated in the southern part of the Krakowsko-Częstochowska Plateau.

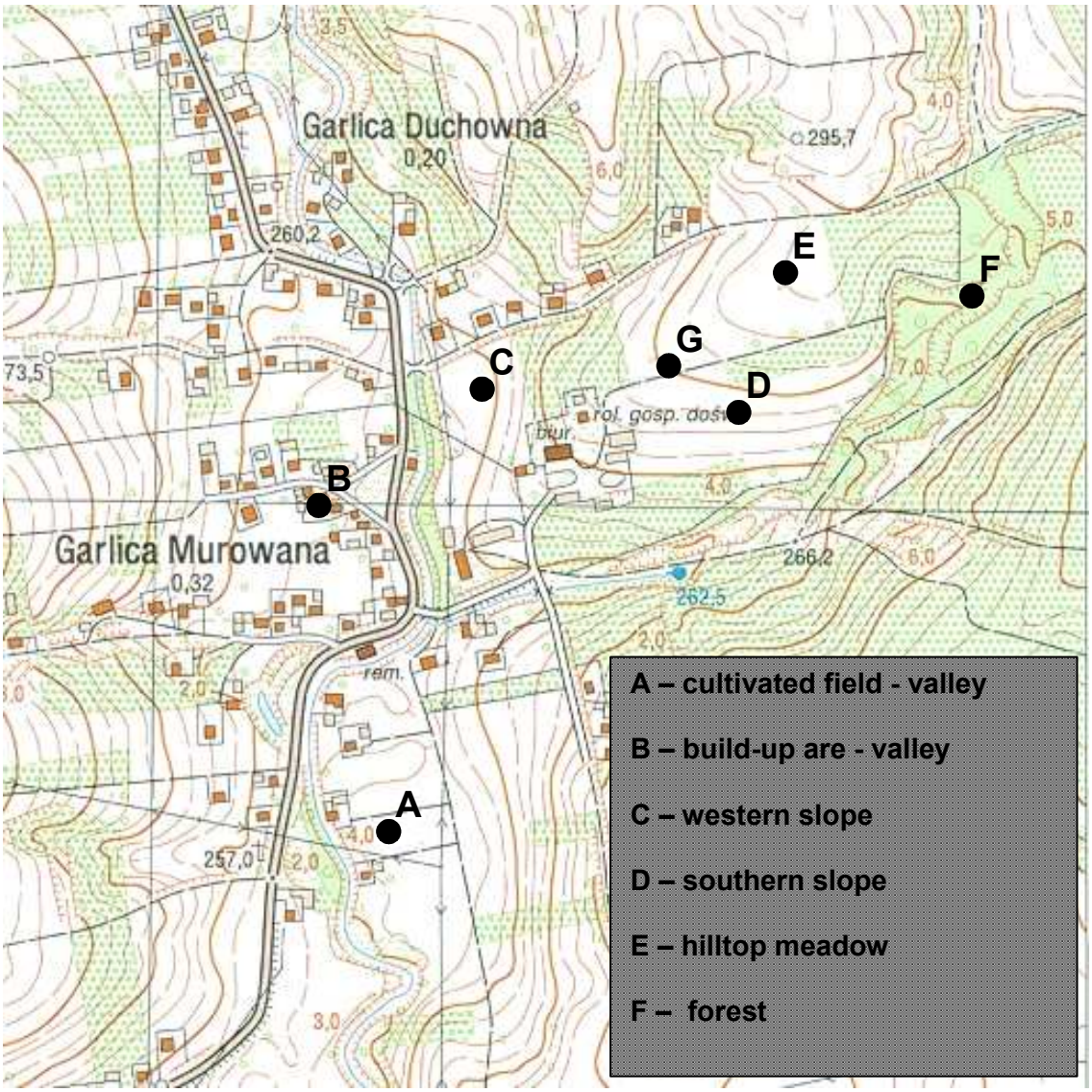

Fig.1. Distribution of instrument shelters in the vicinity of Garlica Murowana

Study area

Field research and meteorological observations carried out in order to comprehend specific features of the local climate are limited to small areas and short temperature series, that are usually available during fair weather conditions near the surface. Air temperature measurements have been conducted in the vicinity of Garlica Murowana (near Krakow). This village is within administrative region, which belongs to Zielonki county. According to the physical-geographical classification (Kondracki 2000) this particular area is situated in the southern parts of Krakowsko-Częstochowska Plateau. The instrument shelters are situated in an agricultural region, which is used by the Chair of Fruit Farming and Apiculture. The instrument shelters are located also in the vicinity of this area which include such topographical features as valley, built-up area and arable field (fig. 1). Terrain depression in this area does not exceed 50 meters (relative altitude).

Materials and methods

In order to determine the quantitative impact of relief and land usage on the thermal conditions at Garlica Murowana (2 meters above surface) the authors have set up instrument shelters equipped with miniature air temperature recorders (Hobo company), which have been mounted in the anti-radiation shields. The air temperature was recorded each hour during spring, summer, autumn and winter. Each season represented a series. From each series sample days have been selected in which radiation weather dominated. The meteorological observations have been conducted from July 2006 until May 2009. Mean, maximum, minimum temperatures as well as diurnal temperature amplitude have been listed in tables, whilst course of air temperature has been displayed in graphs.
Observations posts comprised of various types of land usage and forms of terrain relief. The arable lands comprised of soil field, forest, built-up area, whilst terrain relief comprised of upland, valley, and terrains with western, northern and southern expositions. The selected temperature series have been examined by a non-parametric test of variance analysis (Median Kruskal-Wallis Test, Koronacki et al 2006). Statistical conclusions have been carried out at relevance level α=0,05.

Study results

In order to determine the quantitative impact of thermal conditions resulting from various forms of terrain and land usage, the authors compared air temperature courses for selected days during summer and winter seasons in high-pressure area situations respectively (figs. 1-8). The study area was relatively small, however the relief and land usage turned out to be characteristic features for southern parts of the Krakowsko-Częstochowska Plateau.
Graphs that present daily courses of air temperature, clearly indicate the differences between individual meteorological posts. However it is interesting to note that only during the summer season the variance test has confirmed a significant statistical impact of relief and land usage on the course of air temperature. The calculated statistical probability of the Kruskal-Wallis Test was p=0,0053, at significance level α=0.05.
During spring, autumn and winter seasons it has been confirmed that no significant statistical differences exist in the course of air temperature between individual meteorological posts. The calculated probability during the spring season equalled 0,6812, while during autumn it ranged from 0,205 to 0,727. It should be noted that the lowest probability occurred when temperatures have been compared between the upland and valley posts (0,205). During the winter season the highest probability was obtained and it equalled 0,9981. This means that

terrain relief and land usage does not possess statistically significant impact on the course of air temperature during autumn, winter and spring. However in springtime along with increased insolation and vegetation growth, the statistical significance of terrain relief and land usage increases based on the thermal conditions.
In the period May1-3, 2007 in a high-pressure system area and the inflow of arctic air from the Scandinavian Peninsula frost occurred within the studied region, which was a hazard for cultivated plants. It should be noted that these plants have entered the early phase of vegetation and the fruit orchards have been already in the blossoming phase. Figure 1 depicts clearly the diversity of temperatures between the upland and valley as well as land usage areas. Highest maximum temperatures and diurnal temperature amplitudes occurred in the valley post and at built-up and agricultural posts, whilst the lowest values were observed in the forest. Meanwhile minimum temperatures, which fell below -5°C before sunrise, were lowest in the built-up areas and highest in the forest. The course of air temperature on the slopes and upland terrain are characterized by slightly lower diurnal temperature amplitudes.

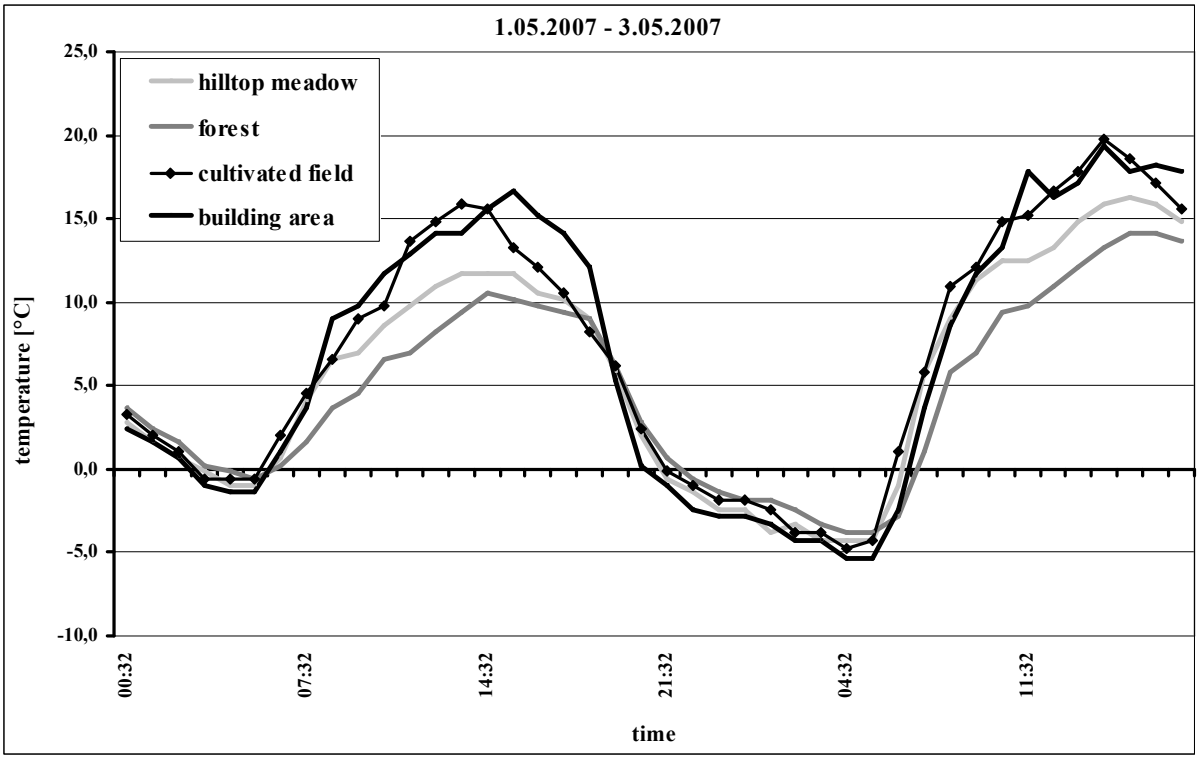

Fig. 1. Daily temperature plot in spring

During the summer season the diversity of mean temperatures and diurnal temperature amplitude is greater than during autumn, winter and late spring. During summer the diurnal temperature amplitudes were highest in the valley and built-up area, and slightly lower in the agricultural region. Temperature drops during the night have been slightly more pronounced in the valley and they also lasted the longest. On the slopes and the upland, where grassy vegetation was present, the course of air temperature was similar. The course of air temperature in the woody environment during each season has been characterized by lowest temperature ranges (fig. 1, 3 and 7).

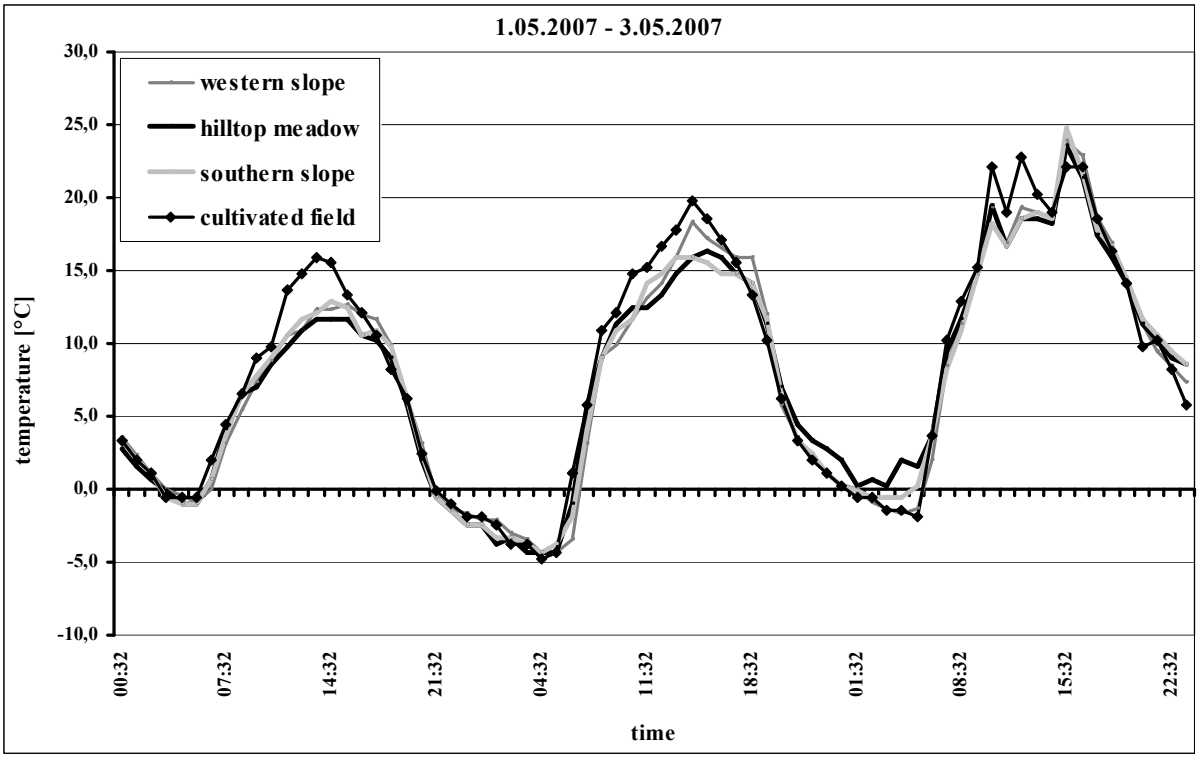

Fig. 2. Daily temperature plot in spring

Tab. 1. Thermal characteristics during spring (1-3.05.2007)

Temperature	**western slope**	**meadow hilltop**	**forest**	**souther slope**	**cultivated filed-valley**	**meadow hilltop**
Mean	7,6	7,6	6,6	7,6	8,2	7,9
Minimum	-4,3	-4,3	-3,8	-4,3	-4,8	-5,3
Maximum	23,9	23,6	19,0	24,8	22,8	24,8
Amplitude	28,2	27,9	22,8	29,1	27,6	30,1

In case of relief terrain, which is typical for the southern part of Krakowsko-Częstochowska Plateau the dynamics of the course of air temperature is dominated by the role of relief and means of usage of arable land over the altitude factor. This research indicates that the highest impact of the aforementioned meteorological elements occurs during summer season. This observation has been confirmed by the K-W statistical test. In particular diurnal temperature range indicated strong association with relief and land usage. They are much higher on the slopes and the upland, whilst during summer much higher in winter and autumn (fig. 2, 3, 7 and 8).

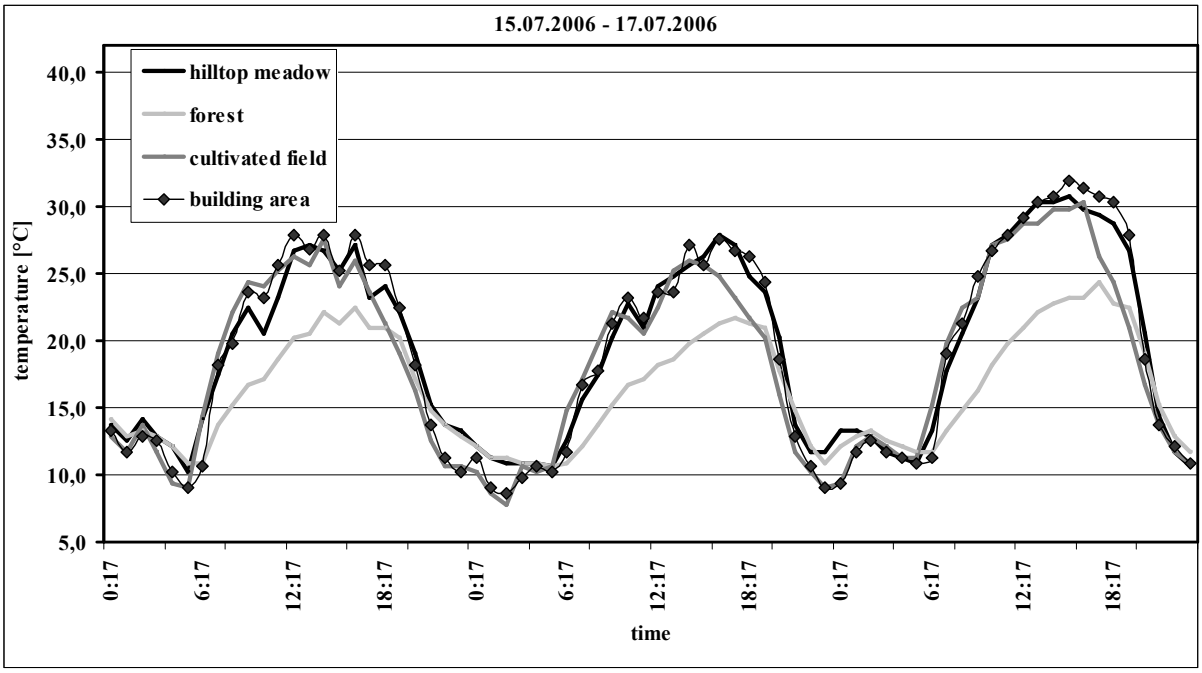

Fig. 3. Daily temperature plot in summer 2006

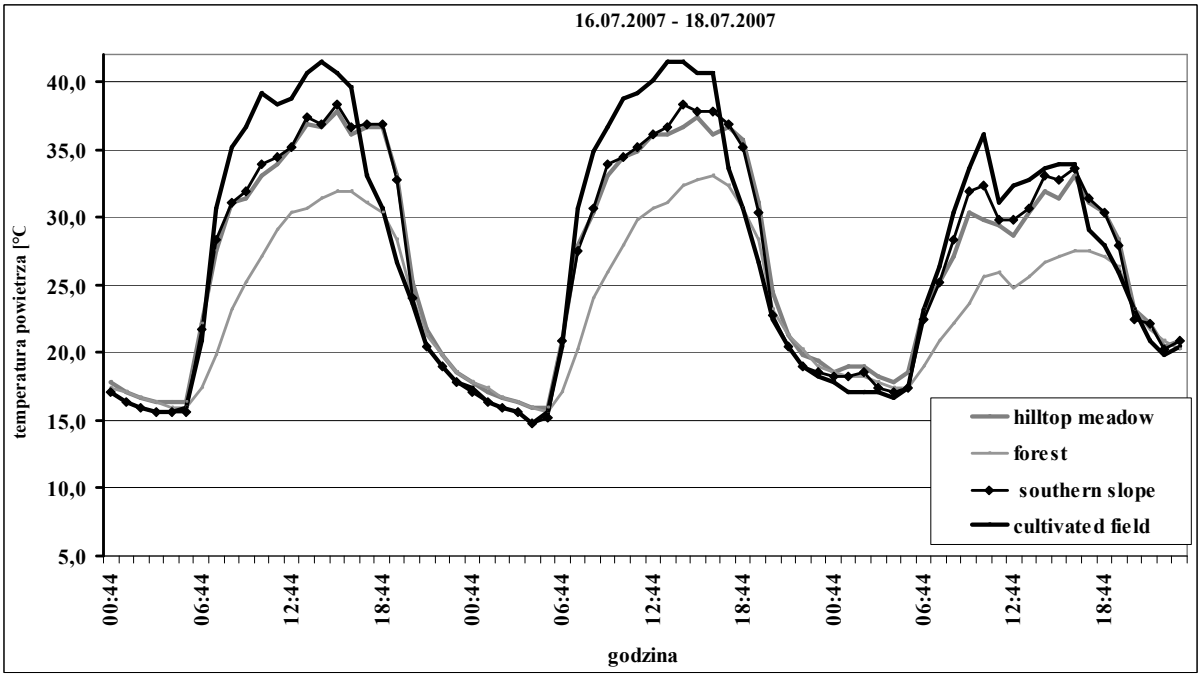

Fig. 4. Daily temperature plot in summer 2007

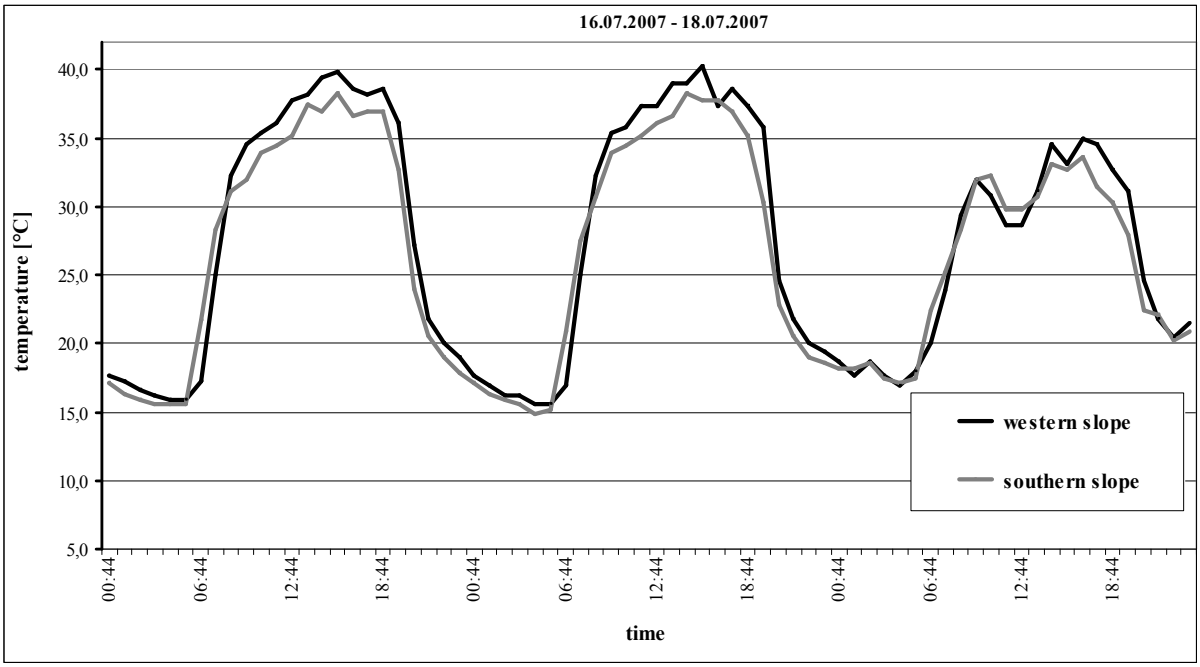

Fig. 5. Daily temperature plot in summer 2007

A more severe thermal regime for the valleys compared with upland and slopes, possesses a very important significance in the selection process of cultivated plants. In particular during springtime one of the most common hazards for cultivated plants is the occurrence of temperature inversions, during which the air temperature drops below freezing (fig.1). The occurrence of temperature inversions is a common feature of relief terrain, especially during the period of negative radiation balance. During summertime the surface layer causes temperature differences between forest, grassy and residential habitats. This is mainly conditioned by the character of the active layers (fig. 3, 4, 5 and tab. 1, 2, 3).

Tab. 2. Thermal characteristics during summer (15-17.07.2006)

Temperature	**meadow hilltop**	**forest**	**cultivated filed-valley**	**meadow hilltop**
Mean	20,5	17,7	19,9	20,3
Minimum	7,8	8,6	7,4	6,6
Maximum	34,4	29,1	36,1	35,7
Amplitude	26,6	20,5	28,7	29,1

The ground coverage especially during summertime creates climatic differences between grassy, forest and built-up habitats (fig. 3, 4, tabs. 2). The properties of the surface layer are decisive in the exchange energy process via radiation (Baranowski 2003). In the studied area the grassy layers on the southern slope and the upland region are characterized by lower temperature amplitudes compared with the western slope and the valley. The western slope was the warmest post during afternoon and early evening hours (fig. 4 and 5, tab. 2).

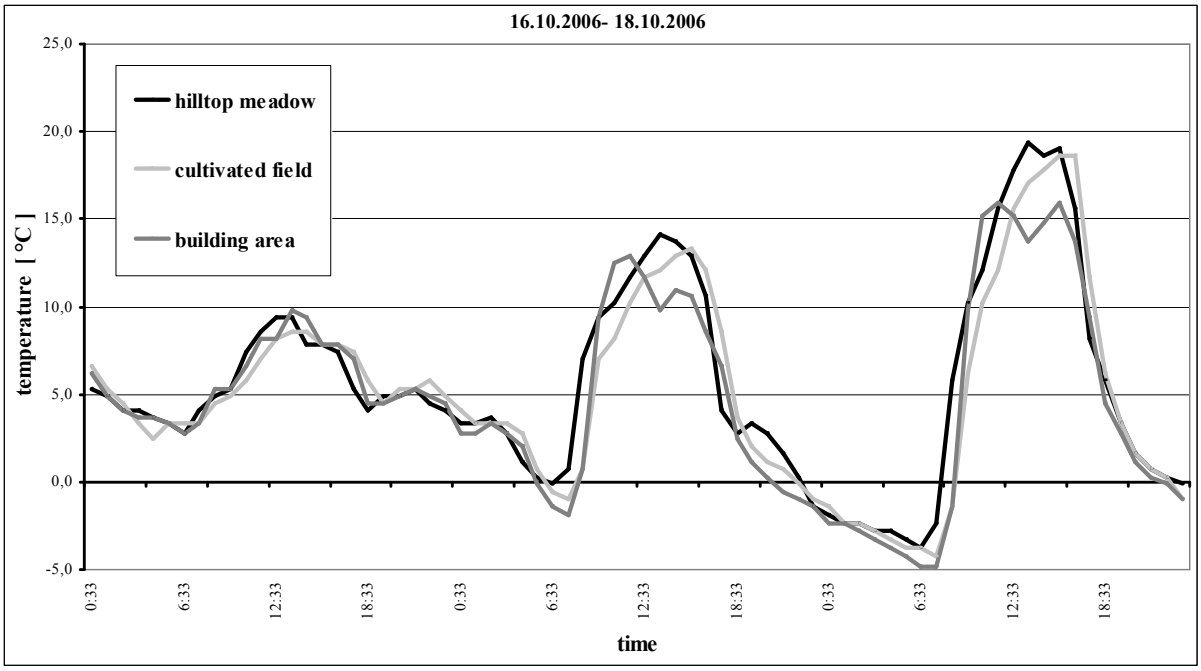

Fig. 6. Daily temperature plot in autumns

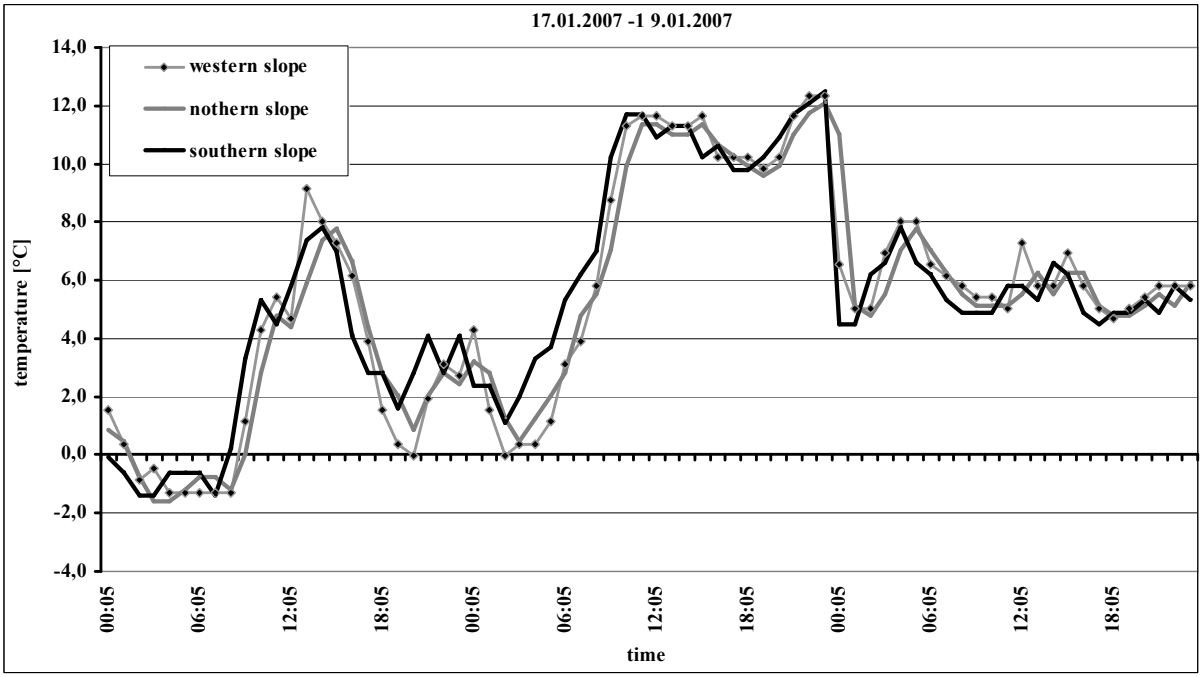

Fig. 7. Daily temperature plot in winter

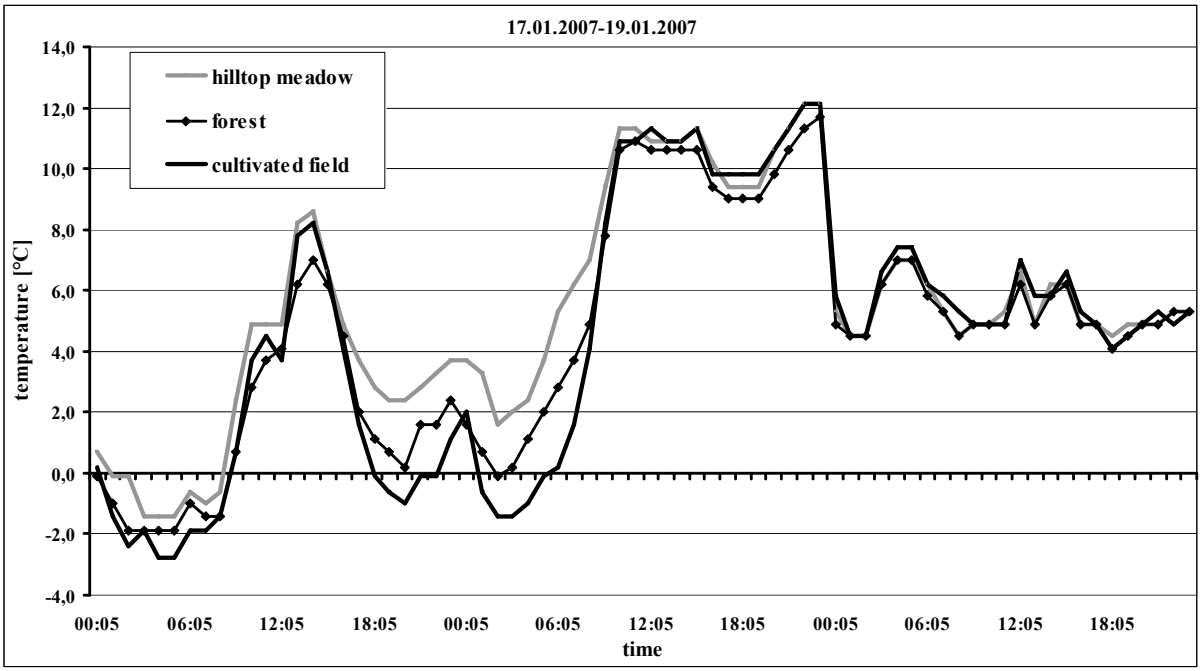

Fig. 8. Daily temperature plot in winter

Tab.3 Thermal characteristics during winter (17-19.01.2007)

Temperature	western slope	northern slope	hilltop meadow	forest	southern slope	cultivated filed-valley	building area- valley
Mean	5,3	5,2	5,4	4,5	5,4	4,4	4,2
Minimum	-1,3	-1,6	-1,4	-1,9	-1,4	-2,8	-3,3
Maximum	12,3	12,1	12,1	11,7	12,5	12,1	11,7
Amplitude	13,6	13,7	13,5	13,6	13,9	14,9	15,0

Concluding Remarks

The goal of this elaboration was to show the quantitative impact of relief and land usage on the thermal conditions in an agricultural area situated in Garlica Murowana. Based on the analyses of air temperature course it was confirmed that there exists an essential statistical impact of relief and land coverage on the diversity of thermal conditions. The obtained results verify the research of other scholars that have been carried out in relief type terrains in southern Poland (Niedźwiedź 1973, Durło and Wilczyński 2006). The highest values of maximum temperature occurred in the base of the valley, however that was also where the greatest drops in temperature during night have occurred. These remarkable drops have been caused by the subsidence of cool air. The most favourable thermal regions are the slopes and the upland, which consequently are exposed longest time in terms of solar insolation. This research indicated the occurrence of temperature inversions throughout the year. Arable lands situated in the valley were susceptible to greatest cooling during nighttime. The most stable thermal conditions occurred in the forest.

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