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Different temperature and humidity responses to the clear-cut and the gap in a Scots pine forest: a study case in Central Poland

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Abstract: Over the past decades, relatively few experimental studies have been carried out in which the micrometeorological conditions have been studied over different small clearings plots of the forest. As these conditions can significantly affect many processes in the ecosystem, two questions arise: 1) whether and how the microclimatic conditions differ in the clear-cut and the gap, and 2) how heterogeneous is the distribution of these conditions on these plots. The aim of the study was to determine the spatial variation of air temperature on the clear-cut and gap as well as to compare the distribution of thermal and humidity conditions on both areas. The research was carried out in Central Poland on a clear-cut with a width of 60 m and on a gap of an ellipsoid shape (40 × 70 m). The measurements were carried out in two series: spring-summer, in the period when the height of the sun during the day conditioned inflow of direct solar radiation to any surface (May–August 2006), and autumn, when direct radiation was limited by neighbouring stands (October–November 2006). Average values of air temperature on the gap in the spring-summer period differed in individual parts of 2.2 °C, while on the clear-cut by 1.0 °C. In the autumn, thermal diversity on both research plots was similar (average 0.8 °C). The thermal diversity within the research areas was particularly marked in the case of extreme air temperature values. We found the modest spatial diversification of humidity parameters: vapour pressure, relative humidity, and humidity deficit. Particularly large diversification of relativity humidity and vapour pressure deficit were claimed in spring-summer period in the situation of heat waves. The least beneficial thermal and humidity conditions for plants growing occurred in the north-east parts of clear-cut and gap, that is why it necessary to take particular note of these locations during undertaking the silviculture.

Keywords: temperature; vapour pressure; relative humidity; vapour pressure deficit

1. Introduction

When conducting the renovation studies on clear–cuts and gaps, it's necessary to take into consideration the specificity of microclimatic conditions which are shaped differently in individual parts of the renovated surfaces. Particularly important are the border zones of regeneration areas and forests, where both the biotic conditions [1] and physical conditions change [2, 3, 4, 5].

Higher air temperature values and low relative humidity near the sunny edge of the forest may reduce the biomass production and disrupt the life processes of many plant species [6]. Increased or, in a different place, limited inflow of solar radiation directly influence on the air and ground temperature. Air temperature determines the atmospheric capacity of water vapour, thus significantly affecting the evapotranspiration, and these factors, together with rainfall, are an important element in drought monitoring [7,8] and predicting [9].

The places with the high insolation are characterized by higher air temperature [10], the increasing value of water saturated vapor pressure and thus the growing deficiency of air humidity and decreasing of the relative humidity.

The processes occurring locally take place under specific macroclimatic conditions, and thus also taking into account contemporary climate change. The growing trend in air temperature, claimed especially since the 1990s [11,12], is accompanied by an increase in moisture deficit, which affects the amount of evapotranspiration, and changes in this parameter are greater than changes in the amount of precipitation [13,14].

Taking into account the importance of the air temperature and humidity conditions for the functioning of forest ecosystems and the conducted breeding works, there was undertaken the research on the diversification of air humidity conditions in the clear−cut and gap. In the studies of this type conducted until now, it has been found that the size of the gap affects the solar and thermal conditions, and thus also the humidity of the air [15,16], and an important factor is also the differentiation of conditions within the same gap [17,18]. Van Dam [19] drew attention to the influence of the gap size on evapotranspiration, which depends on the thermal and humidity parameters of the air. In the context of forest adaptation to the ongoing climate change, it is necessary getting to know about the thermal and humidity conditions of various regeneration areas, with particular emphasis on places exposed to greater climatic stress.

The aim of the study was to determine the spatial variation of air temperature (t), vapour pressure (e), relative humidity (RH), vapour pressure deficit (VDP) on the clear−cut and gap as well as to compare the spatial distribution of air humidity conditions on both areas.

2. Study site, material & methods

The research was carried out in Rogów Forest Experimental Station (51.827023°N, 19.922315°E) on a clear−cut with a width of 60 m and on a gap (of an ellipsoid shape; 40×70 m). The measurements were carried out in two series: spring−summer, in the period when the height of the sun during the day conditioned inflow of direct solar radiation to any surface (May−August 2006), and autumn, when direct radiation was limited by neighboring stands (October−November 2006).

In the central part of the clear−cut along the NW-SE course, the following measurement points were set on the transect putting crosswise: on the edge of the stand and clear-cut on the SW side (z1) and at a distance of 15 m (z2), 30 m (z3) and 45 m (z4) from positions z1. For comparison purposes, a measuring station was also placed 15 m from the z1 station into the forest.

In the central part of the gap, the longer axis of which was directed along the NW-SE line, a transect was marked, on which the measurements were carried out at a station located 10 m from the SW edge of the gap (g1), in the middle of the gap width (g2) and 10 m from the NE edge of the gap (g3). At each measuring station, HOBO sensors were placed in anti-radiation shields at a height of 50 cm above the ground. Data was recorded at 10-minute intervals and was carried out in accordance with the assumptions of the short measurement sequence used in this type of research [18, 20].

Based on the Shapiro-Wilk test, it was found that the distributions of each characteristic were close to the normal distribution ($p < 0.05$). Average and extreme values as well as standard deviation of individual meteorological elements were determined. The Ward agglomeration method was used to determine the measurement stations that were the closest in terms of the analyzed parameters - the Euclidean distance was used as the measure of the similarity of the measurement stations.

3. Results

3.1. Temperature

Average values of air temperature on the gap in the spring−summer period differed in individual parts by 2.2°C, while on the clear−cut by 1.0°C (Table 1). In the autumn, thermal diversity on both research plots was similar (0.8°C on average). The thermal diversity within the research plots was particularly marked in the case of extreme air temperature values. Differences between minimum temperature values in the spring−summer period amounted to 1.8°C on the clear−cut, and

1.3°C on the gap, while in the autumn to 1.0°C on both research plots. Higher differentiation occurred in the case of the maximum temperature: the differences in spring–summer equaled 3.1°C on the clear–cut and 8.7°C on the gap, and in the autumn 2.7 and 3.1°C, respectively.

In May, three late frost days occurred on the clear–cut, while on the gap the no frost was recorded. All late frost situations occurred during radiation weather characterized by weak wind blowing across the clear–cut (Table 2).

Table 1. Average (t) and extreme values, standard deviations (SD) of air temperature in the forest, on the clear-cut (z1, z2, z3, z4) and at the gap (g1, g2, g3).

Measuring point	t	SD	t_{min}	t_{max}	t	SD	t_{min}	t_{max}
	Spring–summer				Autumn			
Forest	16,0	5,17	2,9	31,5	6,4	4,63	-3,9	18,7
z1	15,6	6,36	-0,2	36,6	5,2	4,78	-5,8	17,9
z2	15,3	6,96	-1,1	37,4	4,9	4,89	-5,8	17,9
z3	16,1	7,96	-2,0	39,7	5,1	5,31	-6,8	19,4
z4	16,3	7,81	-1,5	38,8	5,7	5,46	-6,8	20,6
g1	15,0	5,34	2,1	32,8	5,7	4,54	-4,8	17,5
g2	15,6	6,34	2,0	37,9	5,5	4,57	-5,3	17,1
g3	17,2	7,12	3,3	41,5	6,3	4,90	-4,3	20,2

Table 2. Characteristics of frost days at the clear-cut and at the gap as well as at the weather station of Warsaw University of Life Sciences in Rogów in May 2006.

Date	Location where the frost occure	t_{min}	Time with t<0°C	Meteorological station				
				t_{min}	t_{max}	Relative humidity [%]	Wind direction	Wind speed [m/s]
11.05	z2, z3	-0,2	0,5h	0,2	24,5	76	WNW	1,3
15.05	z1, z2, z3, z4	-2,0	5,0h	-0,9	19,9	83	WSW	0,3
16.05	z3	-0,2	0,3h	0,5	24,3	72	ESE	1,6

In the spring and summer period, the thermals at the measuring station located in the NE part of the gap (g3) were similar to those located in the center (z3) and in the NE part of the clear-cut (z4). A separate group were the points lying on the clear-cut near the forest wall (z1) and 15 m from it (z2), while the stations located in the SW and in the central part of the gap (g1, g2) were similar in terms of temperature to the point located in the forest (Figure 1).). In autumn, the thermal differentiation on the examined surfaces was smaller (Figure 1)

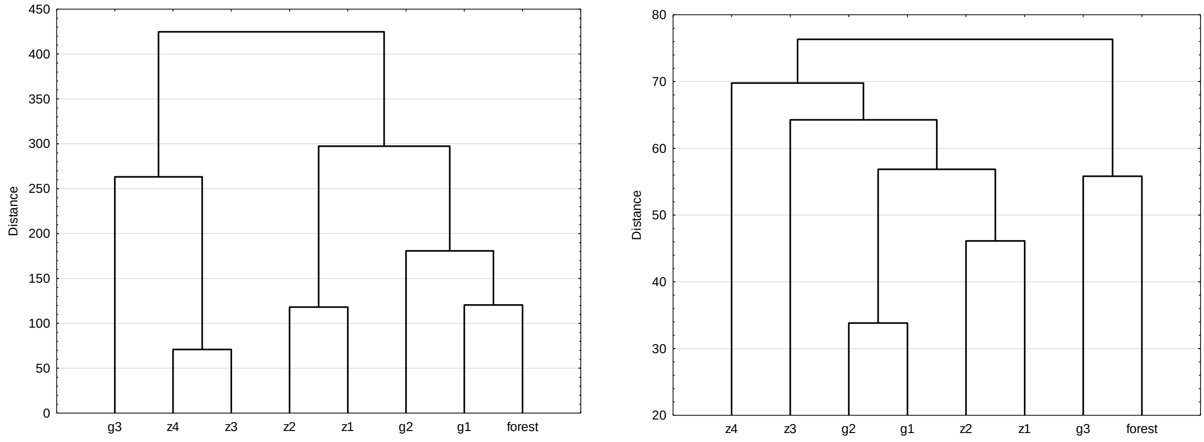

Figure 1 Similarity of research plots in terms of air temperature in the spring-summer (left) and autumn (right).

3.2. Humidity

We found the modest spatial diversification of vapour pressure reaching the mean of 0.4 hPa in spring-summer period and 0,2 hPa in gap and in the autumn period 0,3 hPa and 0,7 hPa respectively (Table 3). The major impact of the clear–cut and gap location was marked in relative humidity and humidity deficit. Differences of relative humidity on the clear–cut amounted averagely to 3.7% and on the gap 12,7%., whereas the humidity deficit 0,3 hPa and 5,4 hPa respectively (Table 3). Particularly large diversification of relative humidity and vapour pressure deficit were claimed in spring-summer period in the situation of heat waves (Table 4). In that weather conditions in sun-filled clear–cut and gap parts, the relative humidity fall to about 17%, whereas vapour pressure deficit increased to about 60 hPa. In the same clear–cut and gap parts the occurrence of dry days was more frequent that in other places. It was noticed that in the positions located in sun-filled clear–cut and gap parts (z4, g3), the diurnal vapour pressure course was very similar to its course in the forest, whereas the course of the relativity humidity and vapour pressure deficit was significantly different. That is mainly involved with the extreme thermal conditions in this parts of studied areas. The least beneficial humidity conditions for plants growing occurred in the north-east parts of clear–cut and gap, that's why it necessary to take particular note of these locations when undertaking the silviculture.

Taking into account the water vapor content in the air (e) in the spring and summer period, more similar to the conditions in the forest are characteristic for the stations located in the clear- cut are more similar to the conditions in the forest, and in autumn in the gap (Figure 2). In terms of relative humidity and insufficient humidity in the spring and summer period, the measurement points located in the SW part of the clear-cut and the gap are similar to the forest. In autumn, the conditions closer to the forest were characteristic for the stations located in the NE part of the studied plots, which was particularly marked in the case of moisture deficit (Figure 2).

Table 3. Average (Ave.) and extreme values, standard deviation (SD) of vapour pressure (e), relative humidity (RH) and vapour pressure deficit (VPD) in the forest, on the clear–cut (z1, z2, z3, z4) and on the gap (g1, g2, g3) in the spring–summer and autumn period.

	Measuring point	Ave.	SD	min	max	Ave.	SD	min	max
		Spring–summer				Autumn			
e	forest	14,4	3,53	4,7	24,9	10,2	2,80	4,3	26,2
	z1	14,5	4,04	4,6	30,6	10,4	3,82	3,7	34,0

	z2	14,5	4,20	5,6	29,2	10,4	3,99	3,9	34,1
	z3	14,1	3,84	4,9	26,7	10,3	3,90	3,7	32,6
	z4	14,3	3,78	6,0	27,3	10,6	3,79	3,9	32,8
	g1	14,6	4,01	5,4	26,7	10,6	3,33	4,5	36,2
	g2	14,7	4,22	6,8	28,5	10,5	3,47	4,3	35,5
	g3	14,5	3,45	5,7	25,9	9,9	2,78	4,1	25,5
RH	forest	77,2	20,08	20,3	100	85,9	13,60	43,8	100
	z1	81,1	22,29	21,3	100	88,7	13,18	50,0	100
	z2	81,5	20,37	24,4	100	89,1	12,59	48,1	100
	z3	77,4	24,21	17,0	100	86,0	13,58	43,9	100
	z4	77,8	24,31	17,4	100	86,4	13,49	44,4	100
	g1	87,2	16,24	25,7	100	92,5	10,78	53,8	100
	g2	85,1	18,39	23,0	100	91,4	11,50	51,7	100
	g3	74,5	24,02	17,0	100	83,4	13,86	41,1	100
VPD	forest	5,5	6,52	0,0	31,1	1,6	1,94	0,0	7,6
	z1	5,3	7,97	0,0	37,1	1,4	1,69	0,0	6,7
	z2	5,2	7,92	0,0	44,6	1,4	1,65	0,0	6,8
	z3	7,5	11,42	0,0	55,9	1,9	2,03	0,0	8,4
	z4	7,4	11,28	0,0	55,6	2,0	2,26	0,0	9,6
	g1	3,2	4,97	0,0	26,4	0,9	1,38	0,0	5,9
	g2	4,4	7,52	0,0	50,6	1,1	1,48	0,0	6,3
	g3	8,6	12,76	0,0	67,9	2,2	2,20	0,0	9,4

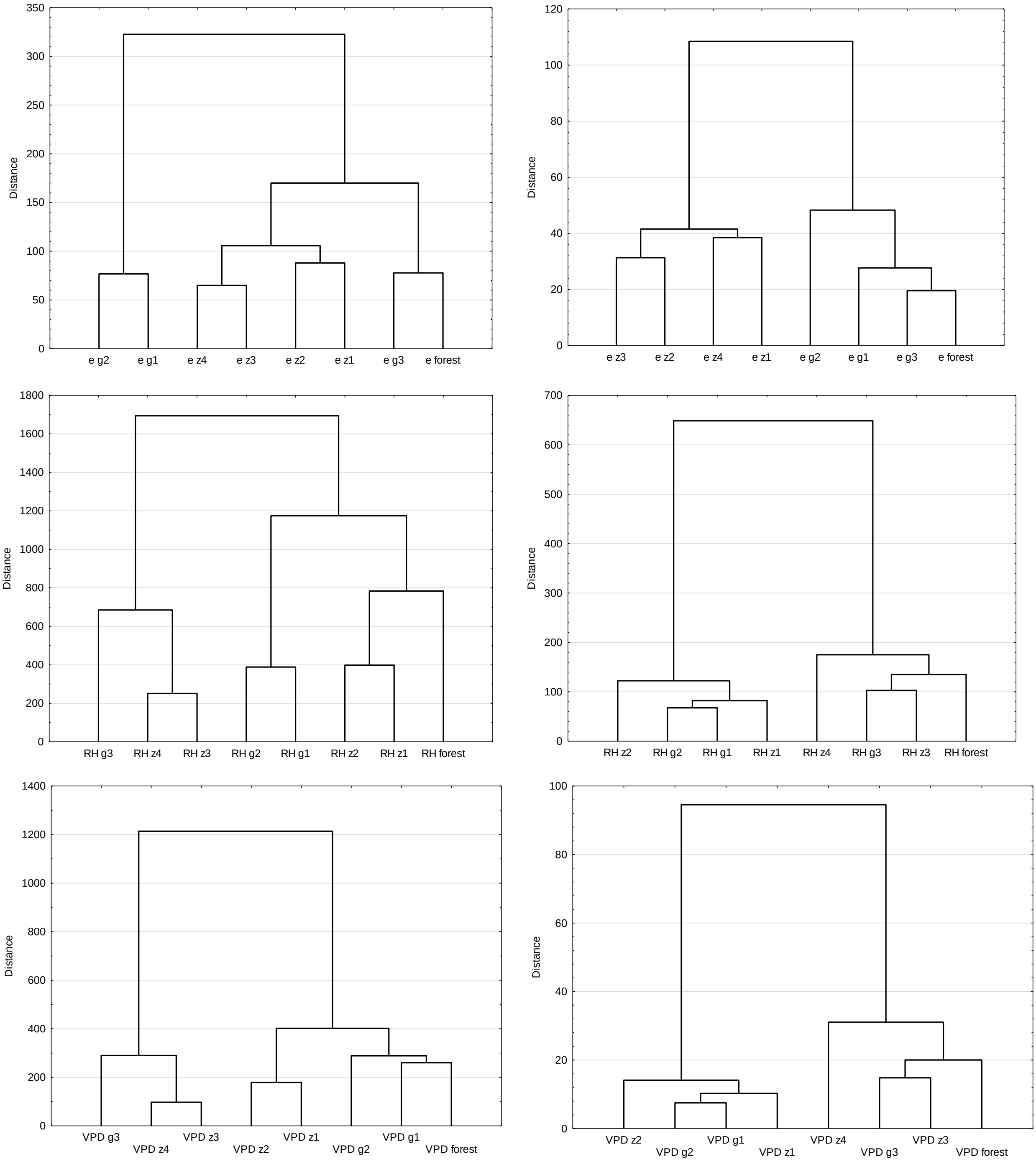

Figure 2. Similarity of the study plots in terms of vapour pressure (e), relative humidity (RH) and vapour pressure deficit (VPD) in the spring-summer (left) and autumn (right) period.

4. Conclusions

The thermal and humidity conditions on the clear-cuts and gaps depend particularly on the elements of the radiation balance, which are shaped differently in their individual parts [21]. In late spring and summer, the insolation on the clear-cut was more diversified, which resulted in a greater diversity of thermal and humidity conditions. A greater risk of extreme thermal conditions (frosts, heat waves) occurred in the clear-cut than in the gap. In the sunny parts of the clear-cut and the gap, extremely low values of relative humidity were found (17% on the clear-cut and the gap) and very high values of humidity deficiency (55.9 hPa on the clear-cut and 67.9 hPa on the gap). Taking into account the high temperature in these places [10] and the importance of moisture deficit for the functioning of plant organisms [6,22,23,24,25], special attention should be paid to weather conditions during conducting renovation studies in these parts of the clear-cuts and gaps.

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