

Proceeding Paper

# Different Temperature and Humidity Responses to the Clear-Cut and the Gap in a Scots Pine Forest: A Study Case in Central Poland <sup>†</sup>

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**Abstract:** In recent 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 the distribution of these conditions is on these plots. The aim of this 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 in 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, during the period when the height of the sun during the day conditioned the 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. The particularly large diversification of relative humidity and vapour pressure deficit occurred during the spring–summer period in the context of heat waves. The least beneficial thermal and humidity conditions for growing plants occurred in the north-eastern (NE) parts of the clear-cut and gap, which is why it is necessary to take particular note of these locations when undertaking silviculture.

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

## 1. Introduction

When conducting the renovation studies on clear-cuts and gaps, it is necessary to take into consideration the specificity of microclimatic conditions which are differently shaped 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 [2–5].

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]. The increased or—in a different place—limited inflow of solar radiation di-

rectly influences 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 important elements in drought monitoring [7,8] and prediction [9].

The places with 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 decrease in relative humidity.

These processes occur locally under specific macroclimatic conditions, and thus also take into account contemporary climate change. The growing trend in air temperature, 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 research undertaken on the diversification of air humidity conditions in the clear-cut and gap. In studies of this type conducted to date, it has been determined 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 to get to know the thermal and humidity conditions of various regeneration areas, with particular emphasis on the places exposed to greater climatic stress.

The aim of this 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 in both areas.

## 2. Study Site, Material and Methods

The research was carried out in the Rogów Forest Experimental Station (51.827023° N, 19.922315° E) on a clear-cut with a width of 60 m and within a gap (of an ellipsoid shape; 40 × 70 m). The measurements were carried out in two series: spring–summer, during the period when the height of the sun during the day conditioned the inflow of direct solar radiation to any surface (May–August 2006), and autumn, when the direct radiation was limited by neighbouring 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 north-eastern (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 were recorded at 10 min intervals and the measurements were 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 the 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 analysed 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 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 the minimum temperature values during 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 equalled 3.1 °C for the clear-cut and 8.7 °C for the gap, and in the autumn, these were 2.7 and 3.1 °C, respectively.

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

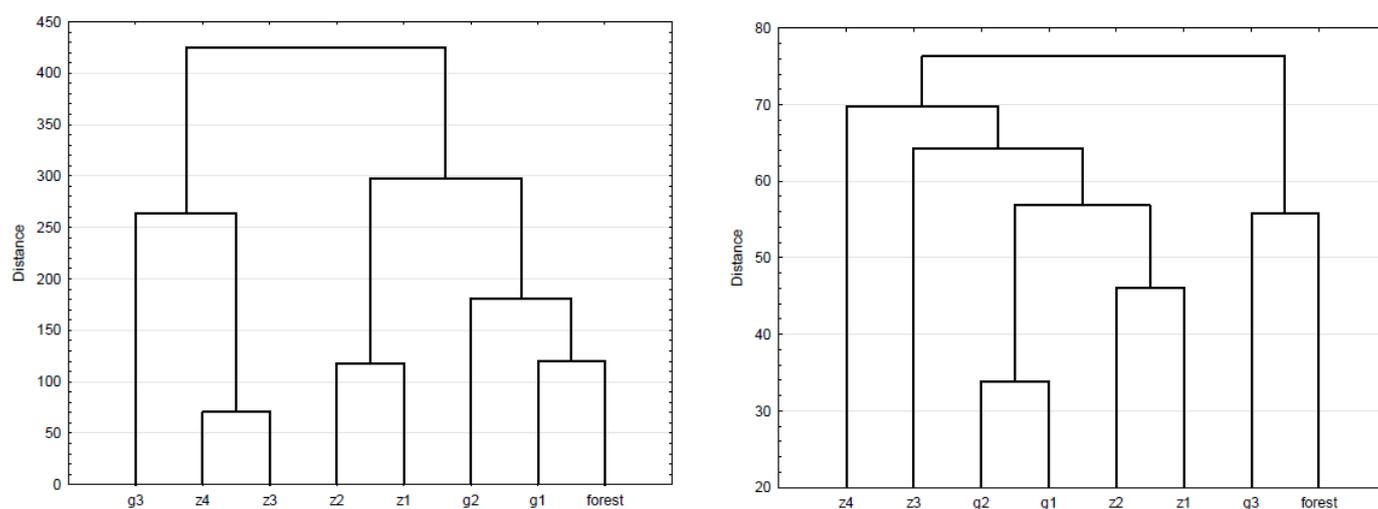
**Table 1.** Average (t) and extreme values, standard deviations (SD) of air temperature in the forest, on the clear-cut (z1, z2, z3, z4) and at the gap (g1, g2, g3).

Measuring Point	Spring–Summer		Autumn	
	t	SD	t <sub>min</sub>	t <sub>max</sub>
Forest	16.0	5.17	2.9	31.5
z1	15.6	6.36	−0.2	36.6
z2	15.3	6.96	−1.1	37.4
z3	16.1	7.96	−2.0	39.7
z4	16.3	7.81	−1.5	38.8
g1	15.0	5.34	2.1	32.8
g2	15.6	6.34	2.0	37.9
g3	17.2	7.12	3.3	41.5

**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 Occurred	t <sub>min</sub>	Time with t < 0 °C	Meteorological Station				
				t <sub>min</sub>	t <sub>max</sub>	Relative Humidity (%)	Wind Direction	Wind Speed (m/s)
11.05	z2, z3	−0.2	0.5 h	0.2	24.5	76	WNW	1.3
15.05	z1, z2, z3, z4	−2.0	5.0 h	−0.9	19.9	83	WSW	0.3
16.05	z3	−0.2	0.3 h	0.5	24.3	72	ESE	1.6

During the spring and summer period, the thermal measurements at the measuring station located in the NE part of the gap (g3) were similar to those located in the centre (z3) and in the NE part of the clear-cut (z4). A separate group was that of 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 at 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).

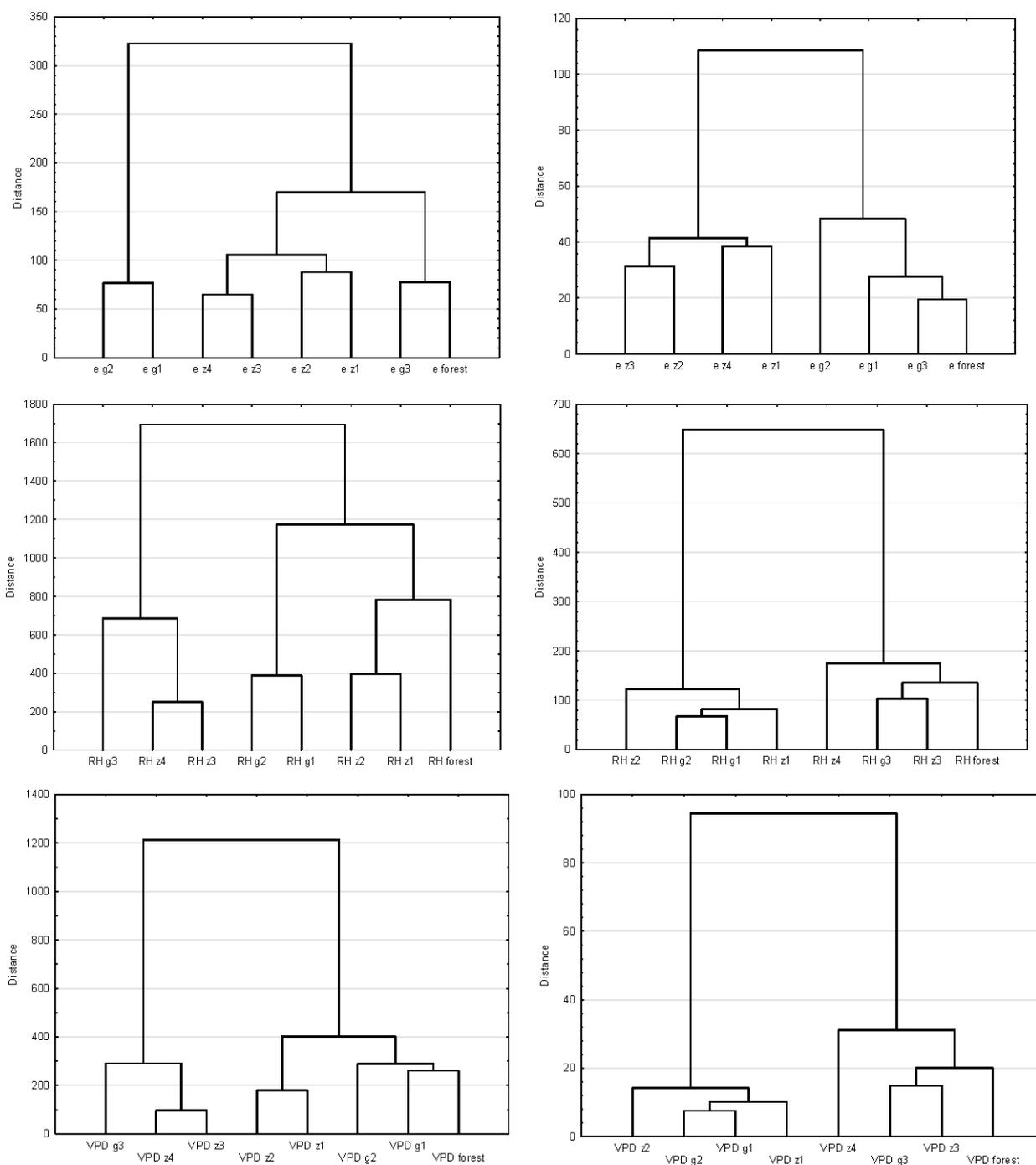
### 3.2. Humidity

We found the modest spatial diversification of vapour pressure reaching the mean of 0.4 hPa during the spring–summer period and 0.2 hPa in the gap during the autumn period, with 0.3 and 0.7 hPa, respectively (Table 3). The major impact of the clear-cut and gap location was marked by a relative humidity and humidity deficit. Differences in relative humidity on the clear-cut amounted on average to 3.7% and on the gap 12.7%, whereas the humidity deficit was 0.3 and 5.4 hPa, respectively (Table 3). The particularly large diversification of relative humidity and vapour pressure deficit were occurred during the spring–summer period in the context of heat waves. Under these weather conditions, in sun-filled clear-cut and gap parts, the relative humidity fell to about 17%, whereas the vapour pressure deficit increased to about 60 hPa. In the same clear-cut and gap parts, the occurrence of dry days was more frequent than 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 relative humidity and vapour pressure deficit was significantly different. That is mainly involved with the extreme thermal conditions in these parts of the studied areas. The least beneficial humidity conditions for growing plants occurred in the NE parts of clear-cut and gap, which is why it is necessary to take particular note of these locations when undertaking silviculture.

The vapour pressure values in the peripheral parts of the clear-cut were similar to the values in the forest in the spring–summer period, while in the gap in autumn (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, in 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 particularly depend 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 [6,22–25], special attention should be paid to weather conditions when conducting renovation studies in these parts of the clear-cuts and gaps.

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