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Recreation in suburban forests – monitoring the distribution of visits using the example of Rzeszów

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Abstract The research aimed to determine the actual distribution of visits in suburban forests in the temperate climate zone, using the Rzeszów metropolitan area as an example. The study also examined whether there is a correlation between the number of visitors to the forests and weather conditions: average daily air temperature, total daily precipitation, and the maximum sustained wind speed within a day. The distribution of visits was determined based on a 365-day monitoring of recreational traffic intensity using a sensor in the form of a pyroelectric detector. Weather data for each day of observation were obtained from a meteorological station. An average of 51 daily visitors was recorded (29 on weekdays and 101 on weekends and holidays). Most people visited the forest during the vacations, in August (14.7%) and July (14.1%), and least in winter: in February (2.7%) and December (3.4%). It was observed that the number of visits to the forest increased with the rise in average daily air temperature. In contrast, as the maximum sustained wind speed increased throughout the day, the number of visits decreased. There was no clear correlation between the number of visits and the total daily rainfall, except for weekends and holidays (number of visits decreased with the increase in rainfall). The number of visitors to suburban forests was more influenced by public holidays than weather conditions. Many forest visitors were significantly more frequently observed on holidays and weekends than weekdays. More than half of all visits occurred on weekends. Forests were most frequently visited on Sundays (38.2%). Suburban forests were visited from 5 AM to 10 PM, with shorter weekend hours (from 6 AM to 8 PM). The results obtained in the study can be valuable for managing recreational activities in suburban forests.

Keywords: forest recreation; forest visitors; leisure time; outdoor recreation; visitor monitoring.

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Introduction

Urban and suburban forests are valuable recreational areas for urban residents and provide the opportunity to conduct ecological and nature-forest education for the public (Janeczko et al. 2021, Korcz et al. 2023). Due to their proximity and general accessibility, they are the primary destination for daily and weekend recreation. Lee et al. (2009) identified landscape and climate as the most important factors influencing the choice of

forest for recreation, followed closely by the accessibility and proximity of the forests. Forests closest to the residential areas constitute the main destination for recreational activities (Lindhagen & Hörnsten 2000, Neuvonen et al. 2007). Forest recreation yields numerous health benefits (Brown et al. 2016, Hansen et al. 2017, Bielinis et al. 2021, Janeczko et al. 2023). This can be attributed to terpenes and terpenoids (Cho et al. 2017, Park et al. 2018, Meneguzzo et al. 2019), whose concentration in forest air is notable. For instance, in pine and beech forests, predominant in the temperate climate zone of Central and Eastern Europe, terpenes and terpenoids constitute approximately 33% of the total volatile organic compounds (Dudek et al. 2022). Janeczko et al. (2020) have argued that, like forests, various forms of urban greenery positively affect visitors' mental and physical health.

A series of studies indicates that forest recreation can be pursued by 76-90% of the population in Poland, depending on the region (Kikulski 2008, Gołos 2013, Dudek 2016). The situation is similar in other developed countries, e.g. in Denmark it is over 90% (Jensen & Koch 2004), 78% in France (Peyron et al. 2002) or approx. 73% in Japan (Cabinet Office of Government of Japan 2007 after Morita et al. 2013).

Nevertheless, it is important to note that these studies are based on survey data, reflecting declared rather than actual numbers of individuals visiting forests. The advantage of survey-based research in this context lies in obtaining results pertaining to all forests rather than solely selected forest complexes where continuous monitoring is conducted.

On the other hand, the advantage of recreational traffic monitoring lies in providing actual results regarding the intensity of activity in selected forest complexes, accompanied by precise diurnal, weekly, and annual distributions (Arnberger 2006, Arnberger & Eder 2007, Ciesielski et al. 2023a,b). Such monitoring has been carried out in national parks for years (Prędki & Demko 2018, Rogowski 2020). However, in those areas, the traffic is channelled and occurs exclusively along designated hiking trails. The number of these trails, with a limited number of entrances and exits relative to the park's surface area, is not high. In urban and suburban forests, where recreational activity may take place not only on designated paths but also freely, comprehensive monitoring of this movement would require the installation of a large number of sensors (at each forest parking area, every road entering the forest).

While technically feasible, implementing such an extensive monitoring system is currently unattainable due to the associated high costs. It is likely that with a reduction in costs, coupled with increasing environmental pressures, the widespread monitoring of tourist and recreational activity in urban and suburban forests will become common in the future, similar to the current practices in national parks. The need for implementing such control in forests was highlighted several years ago by Dudek et al. (2020), who emphasised the risks associated with exceeding recreational capacity (Dudek 2017). Especially vulnerable to various threats arising from human presence are intensively used urban and suburban recreational forests (Referowska-Chodak 2019). Various studies have reported significant damage to soil, young trees and even larger trees in heavily used recreational forests (Kissling et al. 2009, Rusterholz et al. 2009, Dudek et al. 2020, Ozgeldinova et al. 2023).

However, even today, it is possible to precisely determine the preferences of forest visitors regarding their selection of months, weekdays, and hours of the day using individual motion sensors. Until now, such preferences in Polish forests have primarily been determined based on survey research, yielding more general results, for example, related to seasons, times of the day, and distinctions between weekdays and weekends (Janeczko & Woźnicka 2009, Sławski & Sławska 2009, Gołos 2013, Kikulski 2021). Far less common are studies involving continuous monitoring conducted through motion sensors or

camera traps (Ciesielski et al. 2023a, b).

The objective of the research was to improve the understanding of the recreation use of suburban forests by determining the actual distribution of visits in the suburban forests of Rzeszów, with preferences regarding months, weekdays, and hours of the day, utilising modern tools for monitoring tourist and recreational traffic and to provide information that will be useful in the planning and management of suburban forests. Moreover, it was decided to examine whether there was a relationship between the number of forest visitors and weather conditions.

Materials and Methods

The Bór Reserve along with its buffer zone (21°97-22°01′ E, 50°11′-50°14′ N) constitutes the suburban forests of Rzeszów, the largest city in southeastern Poland with a population of 197,000 inhabitants and an area of 129 km^2. The reserve covers an area of 368 hectares, and its buffer zone spans 392 hectares. The reserve includes forest ecosystems, with a large proportion of old-growth trees aged 100-130 years. The tree stands are mainly composed of Scots pine (*Pinus sylvestris*), oak (*Quercus robur*) and beech *(Fagus sylvatica*), which are characteristic of the Sandomierz Forest. The terrain is flat, with absolute elevations ranging from 205 to 235 meters above sea level (Zieliński 2010).

The suburban forests of Rzeszów, located within 20 km of the city limits, cover an area of approximately 30,000 hectares (Dudek 2016). The research was conducted in the Bór Reserve together with its buffer zone. This forest complex, one of the main suburban forest of Rzeszów, is situated to the north closest to the city limits, and is thus frequented by its residents. The number of visitors to the selected suburban forest complex in Rzeszów was determined based on the monitoring of recreational traffic intensity using a sensor in the form of a pyroelectric detector sensitive to changes in temperature emitted by humans. This sensor (PYRO-EVO 2021, Eco Compteur, Lannion, Francja) allows for precise counting, even of rapidly moving individuals. The detection range extends up to 10 meters. In the study, a dual sensor was utilised from October 9, 2022, to October 8, 2023, enabling additional recording of the direction of individuals' movement: it counted how many people entered and how many exited. There are designated trails in the buffer zone and the reserve, which are equipped with recreational infrastructure such as benches, educational boards, and waste bins. Several trails, including where the sensor was installed, lead to a tourist shelter equipped with tables and benches. The sensor was installed on a trail leading from one of the three available parking lots near this forest complex. Every person departing from that parking area to the forest had to pass by the installed motion sensor.

Additionally, meteorological data: average daily air temperature, total daily precipitation, and maximum sustained wind speed during the day for each day of observation were obtained from the nearest weather station – Rzeszów Jasionka (located only 3 km in a straight line from the studied forest complex). As indicated by research from other parts of the world, these are the most significant meteorological factors that influence outdoor tourism and recreation (Lise & Tol 2002, Li & Lin 2012, Aylen et al. 2014, Steiger et al. 2016, Elliott et al. 2019).

The normality of the distribution of the examined features (number of forest visitors and meteorological data) was assessed using the Kolmogorov-Smirnov test (N = 365). As none of the features exhibited a normal distribution, the Spearman rank correlation coefficient was employed to examine the relationship between the number of people visiting the forests and weather conditions [Average Temperature (°C), total rainfall and/or snowmelt (mm), maximum sustained wind speed (km/h)]. The analysis of visit frequency, categorised into non-working days (weekends and holidays) and working days, was conducted using the Chi-square test. All statistical analyses were performed

using the Statistica v13.3 software (StatSoft Inc., Tulsa, OK, USA), and differences were considered statistically significant at the alpha significance level of 0.05.

Results

The sensor recorded 37,031 individuals, with 18,878 entering the forest (in) and 18,153 exiting the forest (out). The difference between individuals entering and exiting consisted of people (3.84%) who chose a different exit point from the forest, not returning to the parking area where the sensor was installed. In further analyses, individuals entering the forest were taken into account. The average daily number of visitors was 51 individuals (29 on weekdays, 97 on weekends, and 101 on weekends and holidays). The maximum number recorded was 453, with only 2 days where the sensor did not register any individuals.

The collected data indicated that the highest number of visitors to the forest occurred during the summer months, specifically in August (14.7%) and July (14.1%). Following those, October (11.9%) and May (11.5%) were the next most visited periods. A peak day was recorded in May: 453 individuals on May 1st. On the other hand, the fewest people visited the forest in February (2.7%) and December (3.4%). In general, it could be concluded from this part of the results that residents of the Rzeszów metropolitan area preferred to visit forests in summer and were least likely to come in winter. In spring, they visited forests more frequently than in autumn (Fig. 1).

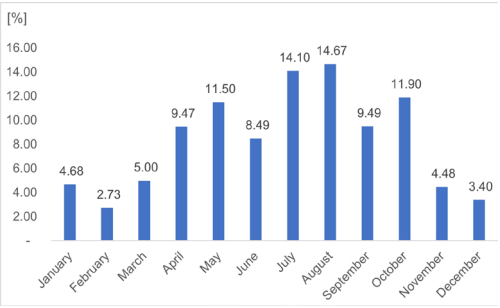

Figure 1 Distribution of visits in selected suburban forest of Rzeszów by months.

Statistical analysis has demonstrated a positive correlation between the number of visitors to the forests and the average daily air temperature: as the air temperature increased, the number of visits to the forest also rose ($r = 0.49$, $p < 0.05$). A weak negative correlation was observed between the number of visitors to the forests and the daily total precipitation ($r = -0.14$, $p < 0.05$), as well as the maximum sustained wind speed ($r = -0.13$, $p < 0.05$), separately included in the analysis. As precipitation increased, the number of forest visits decreased; similar results were obtained for increasing maximum sustained daily wind speed. After excluding holidays, Saturdays, and Sundays from the analysis, the following dependencies emerge: an even stronger relationship between the number of recreational visitors and temperature (recorded in the range of -8.4 – 24.3°C) – positive correlation (Fig. 2), and wind (recorded in the range of 9.4 – 54.0 km/h) – negative correlation (Fig. 3).

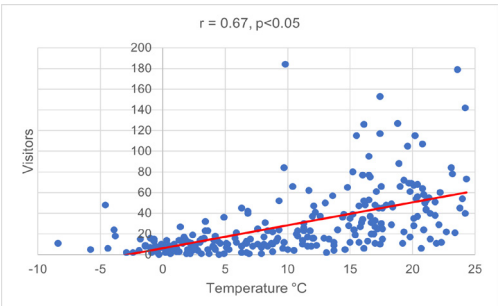

Figure 2 Correlation between the number of forest visitors and the average daily air temperature on working days.

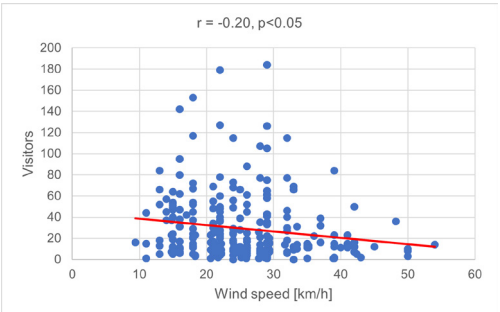

Figure 3 Correlation between the number of forest visitors and the maximum sustained wind speed on working days.

On the other hand, there was a slightly weaker negative correlation between the number of visits and the amount of rainfall (recorded in the range of 0.0 – 22.1 mm) (Fig. 4).

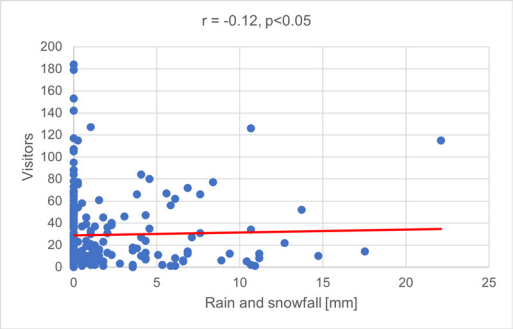

Figure 4 Correlation between the number of forest visitors and the total daily precipitation on working days.

If only non-working days were considered, it appeared that the temperature had a lesser impact on the number of visits to suburban forests, although a positive correlation was still evident ($r = 0.42$, $p < 0.05$). On non-working days, however, the amount of precipitation had a much greater impact on the number of visits, showing a stronger negative correlation ($r = -0.42$, $p < 0.05$) (Fig. 5).

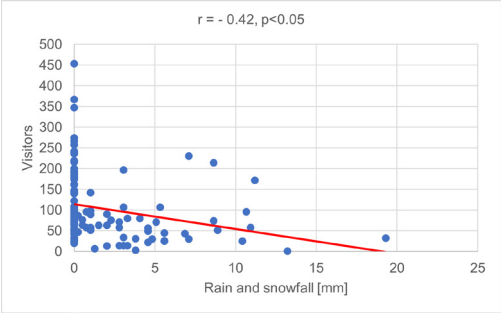

Figure 5 Correlation between the number of visitors and total daily atmospheric precipitation on weekends and holidays.

The number of visitors to suburban forests was significantly more influenced by days chosen for recreation rather than weather conditions. Attendance analysis using the Chi2 test has indicated ($Chi^2 = 129.11$, $df = 6$, $p < 0.001$) that there was a statistically significant relationship between the number of visits to forests and the days of the week (non-working days: weekends and holidays, versus working days). On non-working days, a significantly higher number of forest visitors was observed compared to working days: over 150 visitors were recorded 24 times during non-working days, whereas only 3 times on working days (Table 1).

Table 1 Bivariate table: observed frequencies (Chi^2 test).

Visitors	Weekends and holidays	Working days	Total
0-20	7	138	145
21-40	14	50	64
41-60	19	32	51
61-80	20	19	39
81-110	19	6	25
111-150	8	6	14
>150	24	3	27
Total	111	254	365

Most visits to Rzeszów suburban forests occurred on Sundays (38.2%) and Saturdays, but half as many visitors were recorded on Saturdays (16.1%). It should be noted that Saturdays are days off for civil officers and teachers but not for the entire health service, etc., and not for private companies. The fewest visits to the forest occurred on Wednesdays (6.6%). On the remaining days of the week, the number of visits was similar and ranged from 8.6% to 11.3% (Fig. 6).

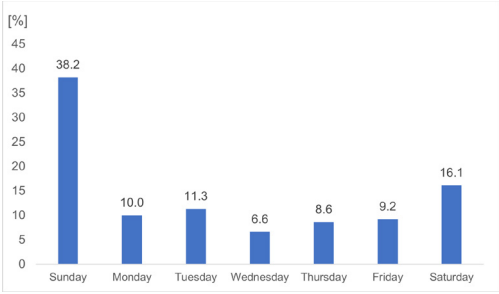

Figure 6 Distribution of visits in selected suburban forests of Rzeszów with respect to days of the week.

The suburban forests of Rzeszów were visited primarily from 5 AM to 10 PM on weekdays, with shorter hours on weekends – from 6 AM to 8 PM (Fig. 8). The distribution of visits during the day showed normal distribution with a peak at 1 PM (13.6% of visitors – entering the forest, Fig. 7). For Saturdays and Sundays alone, the peak hour was also 1 PM (15.2%), while on weekdays, two peak periods

could be observed (Fig. 8): the first one until noon from 10 AM to 1 PM (11.5%), and the second one in the afternoon from 3 PM to 5 PM (9.1%).

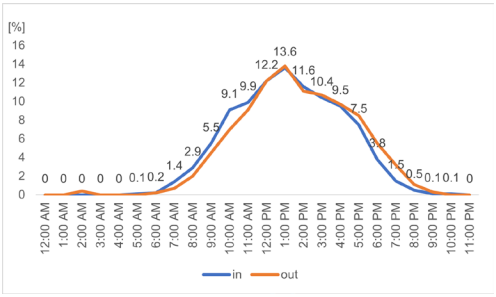

Figure 7 Distribution of visits in selected suburban forests of Rzeszów by time of day.

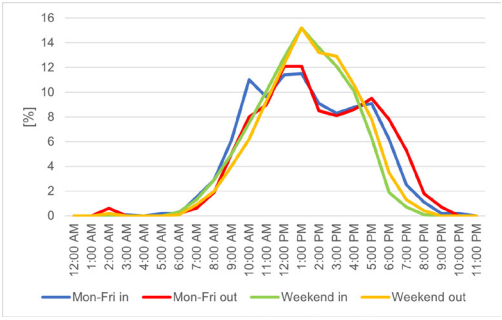

Figure 8 Distribution of visits to selected suburban forests of Rzeszów by time of day on weekdays and weekends.

Discussion

Earlier nationwide survey studies (Kikulski 2021b) have shown that the majority of individuals engage in recreation in forests during the summer (76%) and autumn (74%), followed by spring (58%), with the least participation observed in winter (29%). The same sequence of preferred seasons for recreation in forests was presented by Sławski and Sławska (2009) for residents of the Rogów municipality in central Poland: summer (46%), autumn (41%), spring (24%), and winter (1%). However, in this instance, it could be observed that respondents tended to prefer one specific season for leisure, as the overall percentage was considerably lower compared to Kikulski's work (2021). Warsaw residents, on the other hand, were most likely to engage in recreation in forests in summer (36%), but it was spring (25%) that was more preferred for relaxation than autumn (20%). Similarly to previous studies, the fewest respondents opted for winter (19%). In this survey, respondents were allowed to choose only one season they preferred the most. It is also noteworthy that winter was nearly the favored leisure season for Warsaw residents as autumn (Janeczko & Woźnicka 2009).

The findings on the preferences of residents in the Rzeszów metropolitan area, established in the present study based on active monitoring of visits to a selected suburban forest complex, indicated that the highest number of individuals visited the forests during the summer (38.5%), followed by spring (28.4%) and autumn (21.0%), with the least visits recorded during winter (12.12%). The results obtained in the study closely aligned with the findings of Janeczko and Woźnicka (2009) established based on surveys, with the most notable difference concerning the winter season. However, based on the motion sensor monitoring, more detailed results were obtained, allowing for a precise indication of the distribution of forest visits during specific hours, days of the week, and months. The highest number of individuals visited the forests in August (14.7%), while the lowest was recorded in February (2.7%). Significantly different results in terms of visit frequency to forests in north-central Poland, determined based on 7 photo traps, were reported by Ciesielski et al. (2023a); they registered the highest number of individuals in autumn (36.2%), followed by summer (26.7%), spring (25.7%) and winter (11.3%). In this case, the highest turnout in autumn may result from the research area – "Tuchola Forests" - which is visited, among others, due to the mushroom harvest. Using mobile phone data, Ciesielski (2022) also determined the frequency of visits to forests in the mountainous region of southwestern Poland. This author found that

the highest number of individuals visited the forests in July (12.8%) and June (10.6%), while the lowest visits were recorded in May (4.1%) and November (5.1%). While the results for the highest frequency of visits coincided in a similar period (in the study, in July and August), in the suburban forests of Rzeszów, the least visits were recorded in February, while in May, the number of visits was more than 2.8 times higher than that reported by Ciesielski (2022). In Poland, May 1st and 3rd are national holidays – days off from work.

The study recorded that significantly the highest number of individuals visited forests on Sundays (38.2%), followed by Saturdays (16.1%). On the other days of the week, the number of visits ranged from 6.6% on Wednesdays to 11.3% on Tuesdays. Ciesielski (2023a) utilised monitoring with photo traps and also recorded the highest activity on weekends, with the highest attendance recorded on Saturdays (approx. 35%), followed by Sundays (19%) and Fridays (16%), while Thursdays had the lowest attendance at around 5%. Kikulski (2021) reported that 33.4% of respondents declared recreation in forests on Saturdays and Sundays, while 13.7% chose either Saturdays or Sundays.

In a nationwide study, Gołos (2013) reported that 58% of respondents engaged in recreation in forests on weekends, with an additional 30% doing so on both weekends and weekdays, while 5% only on weekdays. Ciesielski et al. (2019), using data from GPies.com, determined that the highest number of visits to forests in the Sudetes occurred on Saturdays (approx. 23%), while the lowest was recorded on Wednesdays (8%). These authors considered only two forms of activity: hiking and cycling. However, it should be noted that these are collectively the most common forms of forest recreation (Roovers et al. 2002, Arnberger & Eder 2007, Kikulski 2008, Janeczko & Woźnicka 2009, Morita et al. 2009, Agimass et al. 2018).

Arnberger and Eder (2007) established, based on video observations, that more individuals visited urban forests on weekdays (55.9-58.4%, depending on the form of activity) than on weekends, except for walkers (47.8% on weekdays) who constituted 67.7% of all visitors to urban forests in Vienna's 16th district. On the other hand, concerning the suburban forests of Vienna, Arnberger (2006) pointed to the highest visitation frequency on weekends, consistent with the results obtained in the current study.

The findings indicated that the selected suburban forests of Rzeszów were visited from 5 AM to 10 PM, with shorter durations on weekends. The highest share of individuals commenced their forest visits at 1 PM (13.6%), with the highest number of people present at the same time at 11 AM (5.7%). Half of the visits occurred by 1 PM. If only weekdays were considered, two peaks were observed: the first before noon from 10 AM to 1 PM, and the second in the afternoon from 3 PM to 5 PM. It should be noted that such a distribution of visits (without a concentration at one specific time) is favourable both for nature and the forest visitors themselves.

Research indicates that an excessive number of recreationists is one of the primary factors causing disturbance during forest visits, and individuals visiting forests prefer locations with a low number of tourists (Janeczko & Woźnicka 2009, Arnberger et al. 2010, De Meo et al. 2015, Kikulski 2021a).

Similar results regarding daily activity time in forests were recorded by Ciesielski et al. (2023a): from 4 AM to 9 PM, with a peak in visitor registration at 12 PM. Meanwhile, based on survey research, Kikulski (2021b) determined that most people visited forests in the late afternoon – after 3 PM (41.8%), while in the early afternoon – before 3 PM, it was 33.0% of respondents. The remaining 25.2% had no specific preferences regarding the time of day and visited forests throughout the day. These results are similar to those recorded in the present study for weekdays. Greater activity in the afternoon hours often occurs

in urban forests (e.g., Visschedijk & Henkens 2002, Arnberger & Eder 2007). However, the current study found that for suburban forests, around 72% of individuals visited the forest by 3 PM (average daily percentage over the entire observation period). On the other hand, Ciesielski et al. (2019) reported that 74.6% of cycling-related activities began by 1 PM, while 47.6% of walks started by 9 AM.

The current research demonstrated that with an increase in the average daily temperature, the number of individuals visiting forests was also higher (Fig. 2), with maximum average daily temperatures not exceeding 25°C. Similarly, Brandenburg et al. (2007) showed a positive correlation ($R^2 = 0.71$) between the number of recreational cyclists and air temperatures. A similar relationship was determined by Paudyal et al. (2019) for daily maximum air temperature and the number of forest visitors. These authors observed that in Florida (USA), the highest number of individuals visiting forests occurred on days with a maximum temperature of 16-22°C, while temperatures below 6°C and above 31°C significantly reduced the number of visitors. Similarly, Aylen et al. (2014) indicated that the number of visitors to zoos in the UK increased with rising air temperatures up to 21°C, which began to decline. It should be noted that temperature preferences depend on the place of residence of the visitors – the climatic zone (Scott et al. 2008).

The present study demonstrated a weak negative correlation between the number of visitors to suburban forests and the maximum sustained wind speed. A similar negative linear relationship with wind speed was shown for outdoor recreation in England (Elliott et al. 2019).

The study demonstrated a very weak negative correlation between the number of visitors to suburban forests and the total daily rainfall, but only for weekdays (Fig. 4). This could be because precipitation is measured cumulatively throughout the day (including at night), and people may visit the forest at a specific time of day when it is not raining. On non-working days, however, the number of visits noticeably decreased with increasing total daily rainfall (Fig. 5). Paudyal et al. (2019), researching the Florida National Scenic Trail, concluded that days with heavy rain (>25 mm) likely had a negative impact on participation in forest recreation, not only on the day of precipitation but also on the following rain-free day. However, Brandenburg et al. (2007) did not find a relationship between the number of cyclists in Vienna and the amount of precipitation.

Conclusions

The conducted recreational traffic monitoring study using a motion sensor provides new information regarding the distribution of visits to suburban forests of the temperate climate zone, depending on weather conditions, in the Rzeszow metropolitan area.

The vast majority of visitors both started and concluded their visits in the same location, at the forest parking lot (>96%), by 3 PM (72% of visits). This could indicate that the significant majority of individuals visiting suburban forests accessed them with their own vehicles. It has been found that as the average daily air temperature increased, the number of visits to the forest was also higher. Air temperature had a greater impact on the number of visits on weekdays (Monday to Friday inclusive) than on weekends and holidays. The influence of temperature on the number of visits could also be observed based on the preferred seasons, with the highest attendance recorded in the summer and the lowest in the winter. On the other hand, as the maximum sustained daily wind speed increased, the number of visits decreased. There was no clear relationship between the number of visits and the total daily precipitation except on weekends and holidays. During non-working days, the number of visits to suburban forests decreased markedly with increasing rainfall.

Non-working days significantly impacted the number of people visiting suburban forests than weather conditions. On non-working days, a high number of individuals visiting forests

was observed much more frequently than on weekdays. More than half of all visits took place on weekends, most often on Sundays.

The preferences of urban agglomeration residents regarding the time of year, days of the week and hours of the day for visiting suburban forests are indicated. Evidence of a relationship between the number of visits to temperate climate forests and certain weather conditions has also been provided. On weekdays (from Monday to Friday), the air temperature has a greater impact on the number of visits, while on weekends and holidays, precipitation influences the number of visits the most. The results provided in this work can help manage forest recreation in suburban forests.

Compliance with ethical standards

Conflict of interest

The author declares no conflict of interest.

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