Light Pollution Research

Measurements in the Western Carpathians

1. Introduction

Light pollution is the excessive or inappropriate presence of artificial light at night. It is an important environmental issue because artificial light can affect astronomical observations as well as natural ecosystems and human well-being. Reducing unnecessary artificial lighting is therefore relevant not only for astronomy but also for environmental protection and sustainable use of energy.

The **Sport Develops the Mind (SDM)** project combines physical activity, astronomy, environmental education and intercultural learning. One of the planned ecological activities is the measurement of light pollution during a hiking route in the Western Carpathians. Participants were expected to measure night-sky brightness at different locations and compare the results with measurements from inhabited areas and darker mountain environments. The activity was designed as a practical scientific experiment allowing young people to observe how the night sky changes depending on the location and its surroundings.

The measurements presented in this report cover eight observation sites in Slovakia, Poland and the Czech Republic. They include locations in or around settlements as well as rural and mountain areas.

2. Aim of the research

The main aim of the research was to investigate differences in night-sky brightness at selected locations in the Polish-Czech-Slovak border region of the Western Carpathians.

The research had four main objectives:

1. To collect measurements of night-sky brightness at different locations.
2. To compare measurements from more populated areas with measurements from rural and mountain surroundings.
3. To demonstrate how the quality of the night sky changes along the hiking route.
4. To use direct measurements as an educational tool for increasing awareness of light pollution and its consequences for astronomy and the natural environment.

This approach is consistent with the SDM project, in which participants measure light pollution along the hiking trail and discuss its effects on human health, fauna, flora and astronomical observations.

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3. Methodology

Night-sky brightness was recorded at eight observation sites:

- two sites in the Čadca area, Slovakia;
- three sites in the Jaworzynka area, Poland;
- three sites in the Skalka area, Czech Republic.

For each site, three individual sky-brightness readings were recorded. The dataset expresses the measurements in **mag/arcsec²** (magnitudes per square arcsecond) and provides the mean value for each location.

For this type of measurement, a higher numerical value represents a darker sky, while a lower value indicates a brighter night sky and therefore generally stronger light pollution.

The dataset also records the observation night, Moon phase and approximate lunar illumination, as well as atmospheric conditions. These additional observations are important when interpreting the results because the brightness of the night sky can be affected by conditions other than artificial light.

The project application describes the activity as a simple field experiment in which young people measure light pollution and compare results from different environments.

4. Measurement results

The measurements obtained at the eight sites are presented below.

Site ID	Location	Latitude	Longitude	Observation night	Sky brightness readings (mag/arcsec²)	Mean (mag/arcsec²)	Moon phase and illumination	Atmospheric conditions
SK-01	Čadca, Slovakia	49.43752	18.78960	21–22 Jul	20.48; 20.45; 20.51	**20.48**	First Quarter → Waxing Gibbous, approx. 44–54%	Cloud cover: partly cloudy
SK-02	Čadca surroundings, Slovakia	49.44646	18.77133	22–23 Jul	20.28; 20.27; 20.32	**20.29**	First Quarter → Waxing Gibbous, approx. 54–64%	Cloud cover: partly cloudy

PL-01	Jaworzynka, Poland	49.52790	18.85909	24–25 Jul	20.32; 20.30; 20.37	**20.33**	Waxing Gibbous, approx. 73–81%	Cloud cover: partly cloudy
PL-02	Jaworzynka surroundings, Poland	49.52941	18.85380	25–26 Jul	20.11; 20.06; 20.13	**20.10**	Waxing Gibbous, approx. 81–88%	Cloud cover: clear
PL-03	Rural/mountain area near Jaworzynka, Poland	49.52293	18.84711	26–27 Jul	19.96; 19.94; 20.01	**19.97**	Waxing Gibbous, approx. 88–93%	Cloud cover: partly cloudy
CZ-01	Skalka, Czech Republic	49.51971	18.72106	27–28 Jul	19.77; 19.73; 19.78	**19.76**	Waxing Gibbous, approx. 93–97%	Cloud cover: partly cloudy
CZ-02	Skalka surroundings, Czech Republic	49.51245	18.72490	28–29 Jul	19.52; 19.49; 19.55	**19.52**	Waxing Gibbous → Full Moon, approx. 97–99%	Cloud cover: clear
CZ-03	Rural/mountain area near Skalka, Czech Republic	49.51015	18.71761	29–30 Jul	19.35; 19.31; 19.37	**19.34**	Full Moon, approx. 99–100%	Cloud cover: clear

The highest recorded value was **20.48 mag/arcsec²**, measured at SK-01 in Čadca, Slovakia. The lowest value was **19.34 mag/arcsec²**, recorded at CZ-03 in the rural/mountain area near Skalka, Czech Republic.

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The difference between the highest and lowest recorded values is **1.14 mag/arcsec²**. This indicates a substantial difference in measured night-sky brightness between the observation sites.

5. Comparison between countries

The Slovak locations produced the highest average value among the three countries:

- **Slovakia:** average of 20.385 mag/arcsec²
- **Poland:** average of 20.133 mag/arcsec²
- **Czech Republic:** average of 19.540 mag/arcsec²

The Slovak measurements therefore indicate the darkest average sky conditions among the locations included in the dataset, while the Czech measurements show the lowest average sky-brightness values.

However, the number of sites was not identical between countries: Slovakia is represented by two locations, while Poland and the Czech Republic are represented by three each. The results should therefore be treated as a comparison of the measured sites rather than as a representative assessment of the entire three countries or their regions.

6. Differences between locations

The results show a gradual decrease in measured sky brightness across the observation sequence.

In Slovakia, the value decreased from **20.48** at SK-01 to **20.29** at SK-02, a difference of 0.19 mag/arcsec².

In Poland, the three measurements were:

- Jaworzynka: **20.33**
- Jaworzynka surroundings: **20.10**
- Rural/mountain area: **19.97**

The difference between the first and third Polish locations was 0.36 mag/arcsec².

In the Czech Republic, the sequence was:

- Skalka: **19.76**
- Skalka surroundings: **19.52**
- Rural/mountain area: **19.34**

The difference between the first and third Czech locations was 0.42 mag/arcsec².

The data therefore show that the measured night-sky brightness varied between locations, but the available measurements do not allow the differences to be attributed exclusively to artificial lighting.

7. Influence of the Moon and weather

An important limitation of the dataset is that the Moon's illumination changed considerably during the observation period.

The earliest measurements were taken during the First Quarter to Waxing Gibbous phase, with approximately 44–54% illumination. Later measurements were taken with progressively higher lunar illumination, reaching approximately 99–100% around the Full Moon.

This is important because increasing lunar illumination can make the natural night sky brighter. Consequently, the lower sky-brightness values observed later in the measurement sequence may partly reflect the changing lunar conditions rather than an increase in artificial light pollution.

Atmospheric conditions also varied. Some measurements were made under clear skies, while others were made under partly cloudy conditions. Clouds can influence the amount of artificial light scattered in the atmosphere and therefore affect the observed brightness of the night sky.

For this reason, the results should primarily be interpreted as field measurements illustrating differences between observation sites under the conditions recorded at the time, rather than as a controlled scientific survey of artificial light pollution.

8. Interpretation

Despite these limitations, the measurements provide useful evidence of spatial differences in night-sky conditions in the Western Carpathians.

The data demonstrate that night-sky brightness is not uniform across the region. Differences were recorded between locations in settlements, their surroundings and more rural or mountainous environments. This makes the measurements particularly useful as an educational demonstration of the relationship between human activity, landscape and the night sky.

The research also supports the educational objectives of the SDM project. The project was designed to combine astronomy with outdoor physical activity and environmental education. During the hiking camp, participants were expected to compare the mountain sky with skies over inhabited areas and discuss the consequences of excessive artificial light.

The practical character of the activity is particularly important. Instead of learning about light pollution only from theoretical materials, participants collect their own measurements and can directly observe differences between locations. The project proposal specifically identifies this hands-on approach as a way of increasing young people's awareness of environmental problems and the effects of excessive artificial light.

9. Study Design Limitations

The study has several methodological limitations that should be considered when interpreting the results.

1. Limited number of observation sites.
The research included measurements from only eight locations. This provides useful evidence of local differences in night-sky brightness, but it is not sufficient to represent the overall level of light pollution in the Western Carpathians or to make general conclusions about entire countries.

2. Non-standardised environmental conditions.
The measurements were conducted under different weather conditions, including clear and partly cloudy skies. Atmospheric conditions can influence the amount of light scattered in the atmosphere and may therefore affect measured sky brightness. Consequently, differences between locations cannot be attributed exclusively to artificial lighting.

3. Changing lunar conditions.
The measurements were taken during different phases of the Moon, with lunar illumination ranging from relatively low levels to almost full Moon. The Moon is an important natural source of night-sky brightness. Because the measurements were not conducted under the same lunar conditions, direct comparisons between sites should be treated with caution.

4. Lack of repeated measurements under identical conditions.
The available dataset provides measurements from individual observation sessions. Without repeated measurements at the same locations under comparable weather and lunar conditions, it is difficult to determine whether observed differences represent persistent differences in light pollution or temporary changes in measurement conditions.

5. Limited control of other variables.
The study does not provide a fully controlled assessment of factors such as atmospheric transparency, humidity, aerosol concentration, exact distance from artificial light sources, local lighting intensity, or the presence of nearby reflective surfaces. These factors may influence the measured sky brightness.

6. Limited comparability between locations.
The sites differ geographically and environmentally. They are not necessarily equivalent in terms of elevation, surrounding land use, population density, proximity to settlements, or local sources of artificial light. Therefore, the measurements should be interpreted as observations

of particular locations rather than as a controlled experiment in which only one variable changes.

7. The study does not directly measure artificial light emissions.
The recorded sky-brightness values indicate the brightness of the night sky, but they do not by themselves identify the amount, source or intensity of artificial lighting responsible for that brightness. The results therefore provide an indication of night-sky conditions rather than a complete inventory of local light pollution sources.

8. Educational rather than fully controlled research design.
The research was developed as a practical, hands-on scientific activity within the SDM project. The project explicitly describes the measurements as a simple scientific experiment intended to help young participants understand the scale and effects of light pollution. Consequently, the study prioritises accessibility and participant learning rather than the level of experimental control expected in a professional environmental monitoring programme.

10. Environmental and astronomical significance

Light pollution has a direct relevance to astronomical observations because artificial light increases the brightness of the night sky and reduces the visibility of faint celestial objects. This is particularly important in a project that promotes astronomical observations and astrophotography.

The SDM project connects this issue with environmental education. Participants are expected to discuss the effects of excessive artificial light on human health, fauna and flora, as well as its influence on astronomical observations.

The research therefore goes beyond measuring a physical parameter. It provides an opportunity to discuss how human settlements and artificial lighting change the natural night-time environment.

The measurements can also support the promotion of responsible energy use. The project proposes using the results to encourage discussion about sustainable energy consumption and more conscious use of electricity.

11. Educational value

The light-pollution research is particularly suitable for non-formal education because it combines several areas of learning:

- basic scientific measurement;
- astronomy and observation of the night sky;
- environmental awareness;
- geographical orientation;

- data collection and interpretation;
- teamwork and communication;
- digital skills.

The activity also supports the broader SDM objective of combining sport and science. Participants do not study astronomy in isolation: they collect scientific data while travelling through a mountain environment as part of an international hiking camp.

The project identifies the combination of astronomy, sports and environmental education as one of its innovative features and aims to challenge the stereotype that sport and science are separate areas of activity.

12. Conclusions

The measurements collected in the Western Carpathians demonstrate clear differences in measured night-sky brightness between the eight observation sites.

The highest recorded sky-brightness value was **20.48 mag/arcsec²** at SK-01 in Čadca, Slovakia, while the lowest was **19.34 mag/arcsec²** at CZ-03 in the rural/mountain area near Skalka, Czech Republic. The overall range was therefore **1.14 mag/arcsec²**.

At country level, the measured locations in Slovakia had the highest average value (**20.385 mag/arcsec²**), followed by Poland (**20.133 mag/arcsec²**) and the Czech Republic (**19.540 mag/arcsec²**).

The results indicate differences in night-sky conditions across the studied locations. However, the measurements were conducted under changing lunar and atmospheric conditions, so the observed differences cannot be interpreted as a direct measurement of artificial light pollution alone. A more controlled study would require measurements under comparable Moon phases and atmospheric conditions, ideally with repeated observations at the same locations.

Nevertheless, the dataset successfully demonstrates the value of field-based light-pollution research as an educational activity. It makes an abstract environmental problem measurable and visible to participants and connects astronomy with hiking, environmental awareness and scientific learning.

The research is therefore fully consistent with the educational concept of the **Sport Develops the Mind** project: participants learn about their environment through direct experience while combining physical activity, science and non-formal education. The project also plans to disseminate the light-pollution research as an open educational result, making the methodology and findings available to other youth organisations, educators and sports or tourism organisations.

13. Recommendations for future measurements

For future editions of the research, the following improvements would increase the scientific comparability of the data:

1. **Repeat measurements at each site** on several nights.
2. **Standardise the observation time**, for example by measuring at approximately the same time after astronomical twilight.
3. **Control for Moon illumination**, preferably conducting comparisons around the same lunar phase or during moonless nights.
4. **Record exact weather conditions**, including cloud cover and atmospheric transparency.
5. **Use the same measurement procedure and device** at every location.
6. **Include clearly defined reference categories**, such as an inhabited area, suburban area, rural area and recognised dark-sky location.
7. **Record GPS coordinates and elevation** for every observation site.
8. **Increase the number of observation points** to improve the geographical representativeness of the study.
9. **Repeat measurements over different seasons** to investigate whether seasonal conditions influence the results.
10. **Present the results on a map**, allowing participants and the public to visualise changes in night-sky brightness across the Western Carpathians.

Such an extended dataset would make it possible to distinguish more reliably between the effects of artificial lighting, lunar illumination, atmospheric conditions and geographical location.