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HUMANITA

D 2.2.1 Report on testing and data collection in PAs

Location Karawanken-Karavanke UNESCO Global Geopark

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PILOT ACTIONS – Report on testing and data collection

PROJECT PARTNER: EGTC Geopark Karawanken-Karavanke, Carinthia University of Applied Sciences, University of Parma

LOCATION: Karawanken-Karavanke UNESCO Global Geopark + Other Pilot sites (for digital visitor monitoring)

PILOT SITES: Petzen/Peca and Hochobir/Ojstrc

PILOT ACTIONS: Testing new innovative monitoring methods and approaches in Karawanken-Karavanke UNESCO Global Geopark

Table of contents

Table of Figures

VISITOR MONITORING: DIGITAL VISITOR MONITORING for all pilot sites

1.1. STARTING DATE

The data collection of GNSS data from various outdoor– and fitness apps already started in the first period of HUMANITA project (May 2023) and is an ongoing activity. To the current stage CUAS collected data from the **fitness app Strava Metro** and **the outdoor apps Outdooractive, Komoot and Bergfex** for all of our pilot sites.

1.2. METHODOLOGY DESCRIPTION

Data from the outdoor and fitness apps Bergfex, Komoot, Outdooractive and Strava were analyzed to **estimate spatial hot- and lowspots of visitors** within our pilot areas. The goal was to identify official and unofficial user activities that are frequently promoted on these platforms, potentially pointing to future potentials for touristic / recreational development or conflicting activities within protected areas.

Data from pilot sites for all our protected area partners was downloaded for that purpose:

- Karawanken-Karavanke UNESCO Global Geopark
- Bükk National Park
- Mala Fatra National Park
- Significant Landscape Lower Kamenjak
- Tuscan-Emilian Apennine National Park

Most of the outdoor apps provide gpx files showcasing tour suggestions that were uploaded either by official tourist operators, Alpine Associations (i.e. ÖAV) or regular “community” users. Other apps allow users to share POIs with other app users. Some apps suggest tours based on automatic algorithms. Tour suggestions and POIs can be rated and commented on. Tour suggestions can also be downloaded, some apps require a “Pro” account to do so. The fitness app Strava provides a service for companies and organisations involved in active transportation planning, allowing the estimation of trail users along each segment of the street network (based on OSM).

Depending on the app different information about the suggested tours are available online. The following section provides an overview about the information extracted from the apps which we use for our visitor analysis. When analysing the data it is important to keep in mind that it only represents complementary information about visitor's spatial distribution. It is not representative of the total visitor activities of an area, as it only addresses the individual app users.

1.2.1. STRAVA Metro

Strava Metro for visitor monitoring

Strava Metro is a data service that provides aggregated, anonymized insights from the global Strava community to urban planners, transport authorities, and researchers. Strava aggregates millions of user activities and snaps them to a routable street network which is based on OSM data (highway edges). Strava removes personal identifiers, and **produces heatmaps, user counts, statistics and peak usage times**. Metro data is offered via dashboard and map, data can be visualized and downloaded for further use following the **Strava Metro Terms of Use** prior to downloading. Prior consent needs to be required from Strava Metro before publication of any analysis.

Data processing for visitor monitoring

For the purpose of visitor monitoring, the following workflow was used to collect and analyse data from Strava Metro:

- CUAS was granted access to all partner regions:
  - Geopark Karawanken
    - Koroska (Slovenia)
    - Carinthia (Austria)
  - Bükk National Park
    - Borsod Abauj Zemplen (Hungary)
    - Heves (Hungary)
    - Nograd (Hungary)
  - Tuscan-Emilian Appennine National Park
    - Emilia Romagna (Italy)
    - Toscana (Italy)
  - Mala Fatra National Park
    - Zilinský (Slovakia)
  - Significant Landscape Kamenjak
    - Istarska (Croatia)
- Monthly and yearly data were downloaded for the past 5 - 6 years (2019 - 2024). For some areas data for 2019 is missing due to an update of STRAVA Metro Dashboard – data for 2019 was no longer available.
- Theoretically, daily and hourly values are available from Strava Metro but as the accuracy of the data is indirectly proportional to the length of the timespan (minimum valid count is 5 users per time span and users are counted in steps of 5) we decided to focus on monthly and yearly values. The time resolution will be dependent on the context of the study area (rural or urban area), the amount of users and the research question.
- STRAVA Metro provides a **shp file** with a corresponding **csv file with metadata** for every download. Every edge in the shp file has a unique ID that can be linked with the csv file.

- The files were processed via different python scripts.
    - Monthly and yearly data tables are created that are suitable for symbolization in GIS systems
    - Empty edges are deleted for data efficiency
    - Data is clipped to our areas of interest (protected areas between Nature Park Dobratsch and Prealpi Giulie Nature Park) and cleaned of double datasets
    - The following result layers were included into our project
        - Yearly data is available from 2019/20 to 2024 in separate layers.
        - Yearly data from 2020 to 2024 were merged to a joint layer, summed up
        - Montly data is available from 2019 to 2024 in separate layers, each column representing one month
- The data was symbolised in QGIS as a vector line heatmap.
- The categories are based on the statistical method by Jenks, which means that the values within a group are as similar as possible and the groups are as different as possible. For different areas of interest different extends were used, as the visitor counting differs highly between the project sites.

1.2.2. Outdooractive

For the purpose of visitor monitoring, the following workflow was used to collect and analyse data from Outdooractive:

- gpx-tracks of Outdooractive tours were manually downloaded. A simple query of the areas of interest were made (e.g., Petzen, Hochobir).
- Tour ID (from URL) and metadata were documented in an Excel file (metadata: "Created on", "Teasers", "Page views", "Actions", "Printouts downloads", "Link to the tour")
- The downloaded gpx-tracks are automatically named with the Tour ID (from URL) by Outdooractive
- Conversion of gpx-tracks to shapefile, adding Tour ID to each feature using a python script
- Link Excel file to shapefile via Tour ID
- Calculation of a **"Tour Score"** to rank the tours by importance based on estimated usage. The Tour Score provides a standardized measure of route popularity and user engagement. To create the "Tour Score" the metadata/statistics "Created on", "Teasers", "Page views", "Actions", "Printouts downloads", "Link to the tour" were min-max scaled (see description for Komoot app), weighted and summed up.
- To ensure comparability between routes of different ages, the score is based on ***average daily activity*** rather than total accumulated activity. Since routes that have been online longer naturally collect more views and interactions, each activity measure is normalized by the number of days the route has been published.
- The Tour Score is then calculated as a weighted sum of the normalized activity measures:

Tour Score (PVV) = (0,17 "Page views" per day normalized + 0,45* "Printouts and downloads" per day normalized + 0,35* "Actions" per day normalized + 0,03* "Teasers" per day normalized)*

1.2.3. Komoot

For the purpose of visitor monitoring, the following workflow was used to collect and analyse data from Komoot:

- gpx-tracks of Komoot tour suggestor were selected by radius on the map and downloaded manually within our areas of interest
- Tour ID (from URL) and metadata were documented in an Excel file (metadata: “used by” (how many people used the tour), “rating” (average rating of the tour), “number of ratings”, “actuality” (download date – creation date), and “Link to the tour”)
- The downloaded gpx-tracks were named with the Tour ID (from URL)
- Conversion of gpx-tracks to shapefile, adding Tour ID to each feature using a python script
- Link Excel file to shapefile via Tour ID
- Calculation of a **“Tour Score”** to rank the tours by importance based on estimated usage. The Tour Score provides a standardized measure of route popularity and user engagement. To create the “Tour Score” the metadata “used by”, “rating”, “number of ratings” and “actuality” were min-max scaled, weighted and summed up. To ensure comparability across different activity measures, all raw values were rescaled to a common range using min-max scaling. This step prevents measures with larger numerical ranges from dominating the Tour Score.
- Min-max scaling transforms each value x of a measure according to the formula:

$$\text{Scaled value} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

- This procedure rescales all values to fall within the interval [0,1], where 0 corresponds to the lowest observed value and 1 corresponds to the highest observed value. The resulting scaled values are dimensionless and directly comparable across measures.
- For the parameter “actuality”, the formula had to be inverted, as shorter timespans with high rating indicate a stronger impact of the route (1 - Scaled value).

Tour Score = 0,6”used by” normalized + 0,15*”rating” normalized + 0,15* “number of ratings” normalized + 0,1* “actuality” normalized*

All values that are empty will be set as “0” for the formula.

Limitations of the workflow:

- The Komoot tour suggestor generates tours by a selected radius on the map. When the browser window is closed, the same tours cannot be reproduced. Starting from selected highlights, Komoot also allows users to generate tours around these highlights. This way usually more tours are suggested then generating them by a selected radius on the map. This means that not all routes are represented in our analysis.

- There is no information in which period these visits occurred and not every route suggestion has metadata.
- As Komoot is updating their content on a regular basis, the provided content (and eventually the ID) is fluent.

1.2.4. Bergfex

Data processing for visitor monitoring

In contrast to Komoot or Outdooractive, Bergfex does not provide data usable to calculate an estimated usage of their tours.

- gpx-tracks of Bergfex tours were manually downloaded by selecting iIndividual tours on the map for different activity types (pedestrians and cycling).
- Processing of data using python scripts. The main workflow was divided into three steps:
  - **Preparation of a network layer:** OSM data with the **key:highway** were downloaded for the areas of interest. The OSM data needed to be cleansed and processed, to establish a correct network layer
  - **Preparation of Bergfex layer:**
    - Segmentation of all Bergfex tours into single edges (= vector between two nodes of a line).
    - Spatial join counting all adjacent edges of Bergfex tours in a dedicated buffer zone around each edge. To prevent double counting, each Bergfex tour edge received a unique ID, each unique ID was only counted once per edge.
    - The result is a **"tour count value"** for each segment.
  - **Transferring the tour count value on the network layer:** The "tour count value" was interpolated onto the network layer. The distance parameter of the buffer was manually corrected to ensure a minimal error for the attribution.

The resulting network layer shows the density of promoted tours along a dedicated path. **With a higher number of promoted tours a higher usage can be assumed.** The result is similar to the STRAVA Metro data, except it is not showing the user count for each path section, but the tour count provided on this path.

1.2.5. Combined outdoor activity offers Outdooractive, Komoot and Bergfex:

Finally, all downloaded gpx tracks from Outdooractive, Komoot and Bergfex were combined and processed in the same way as the Bergfex data. The resulting layer shows the content density for all three outdoor apps, concerning the provided tours. The higher the density the more usage can be assumed.

1.3. RESULTS AND OBSERVATIONS for Karawanken-Karavanke UNESCO Global Geopark

A **visitor questionnaire (A3.1)**, which was applied in the second period of HUMANITA project has shown that only a relatively small percentage of visitors use outdoor and fitness apps for planning, navigating and tracking their activities within all of our protected area's pilot sites. We noted variations in the type of apps used and the amount of users depending on the area/country as well as the user type (pedestrians /cyclists). Cyclists tend to use outdoor and fitness apps more often than pedestrian visitors.

The **actual number of trail users cannot be accurately determined when analysing data from outdoor and fitness apps.** However, the information from these apps provide valuable insights into the vast amount of digital trails promoted on those apps. It gives information about frequently used and less frequently used trails.

Community routes on these apps **are not always official and may lead to illegal activities** within the areas. **Managing information on these platforms becomes a crucial task for protected areas** to **guide visitors and prevent the development of illegal activities and / or wild trails** and their promotion within the online community.

Some protected areas have started to employ **"digital rangers"** to handle this responsibility and monitor the data on diverse outdoor and fitness apps on a regular basis. They **collaborate with outdoor app providers and the app community** to control information on these apps.

Within the Karawanken-Karavanke UNESCO Global Geoaprk we concentrated on the download and analysis of outdoor app data focussing on our pilot areas (Petzen and Hochobir) and the area inbetween. In total, we downloaded 492 pedestrian tours and 476 cycling tours that are promoted on Outdooractive, Bergfex and Komoot app.

Table 1: Overview of downloaded tours from outdoor apps.

	Pedestrian Tours	Cycling Tours
Outdooractive	118	36
Bergfex	128	25
Komoot	246	415
	492	**476**

We identified a lot of activities that are not in favor of local regulations. Especially for mountain bikers in Austria there are strict regulations for accessing forest roads, alpine pastures or hiking trails. Access is only allowed with prior permission of ground owners, forest authorities and in case of protected areas the nature conservation authority. The process of evaluation and development of recommendations is still ongoing in the 6th period of HUMANITA project.

The subsequent pages illustrate the results of the analysed data from outdoor and fitness apps. While Strava Metro data gives information about the average number of app users that walked or cycled across the trails the outdoor app data shows tours from official providers (tourist operators, alpine associations, etc.) or community users). Depending on interaction rates with the tours they receive a tour score which is weighted as "high or low estimated usage".

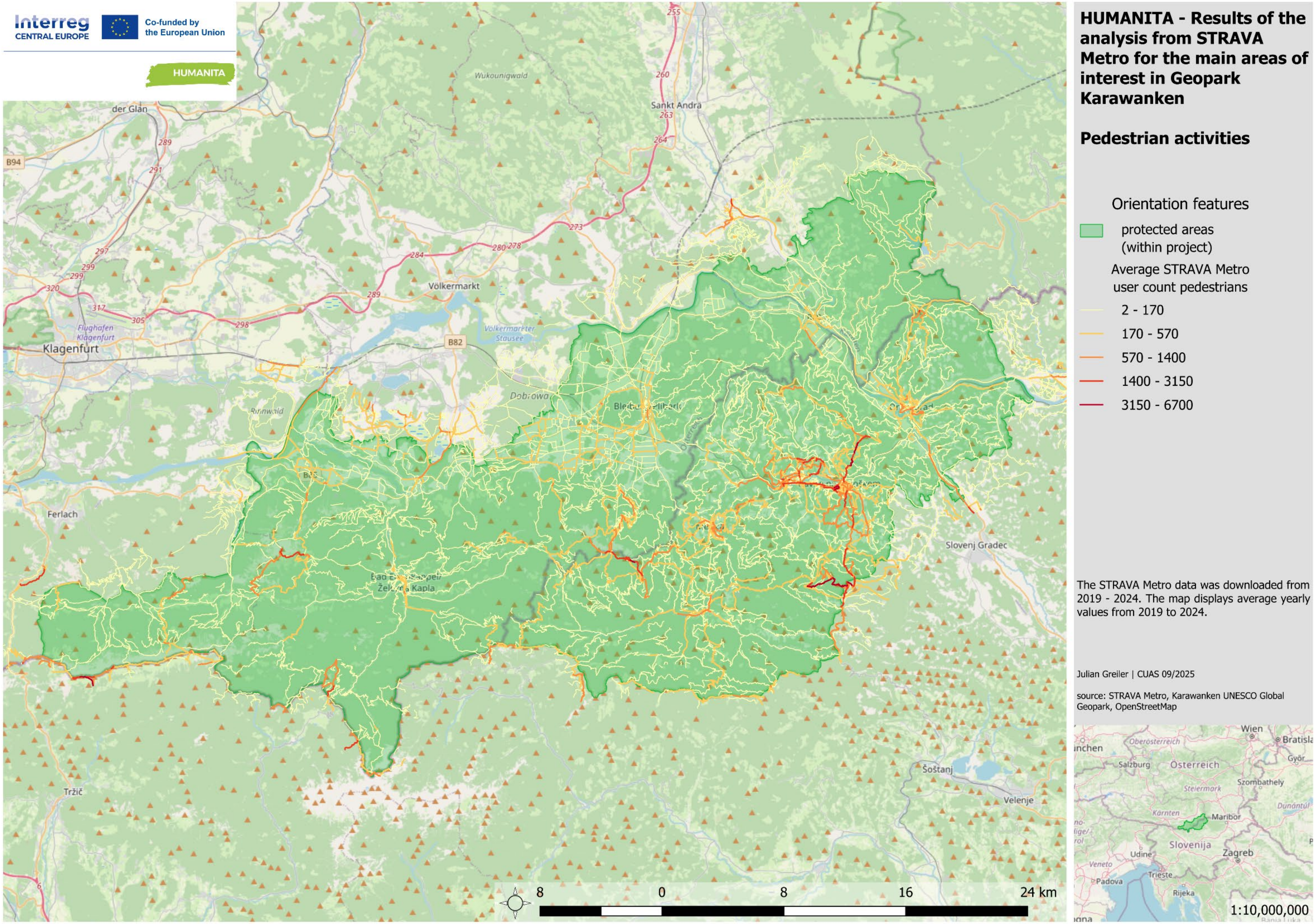


Figure 1: Karawanken UNESCO Global Geopark: Strava Metro Average Pedestrian activities from 2019 - 2025.

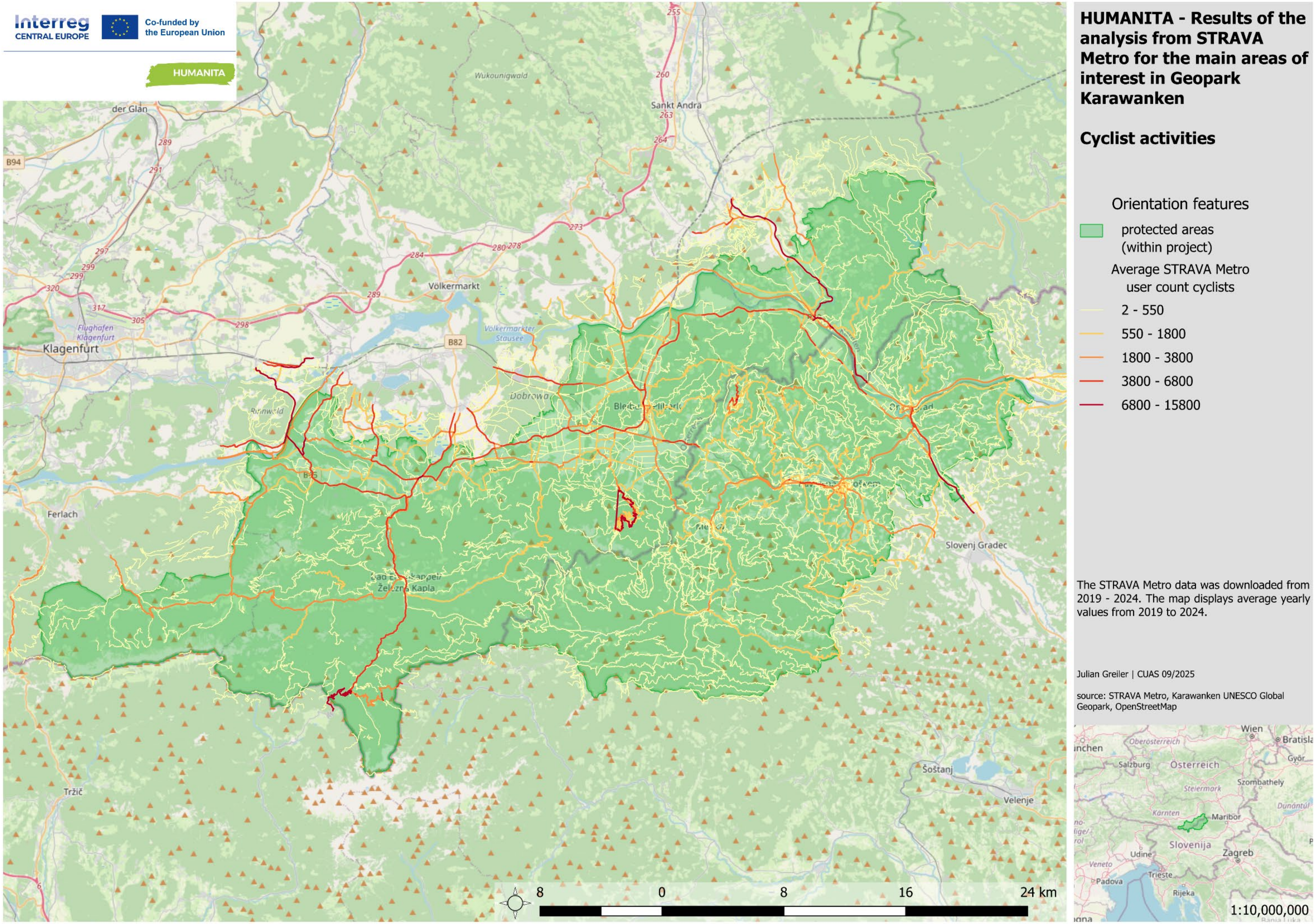


Figure 2: Karawanken UNESCO Global Geopark: Strava Metro Average Cyclist activities from 2019 - 2025.

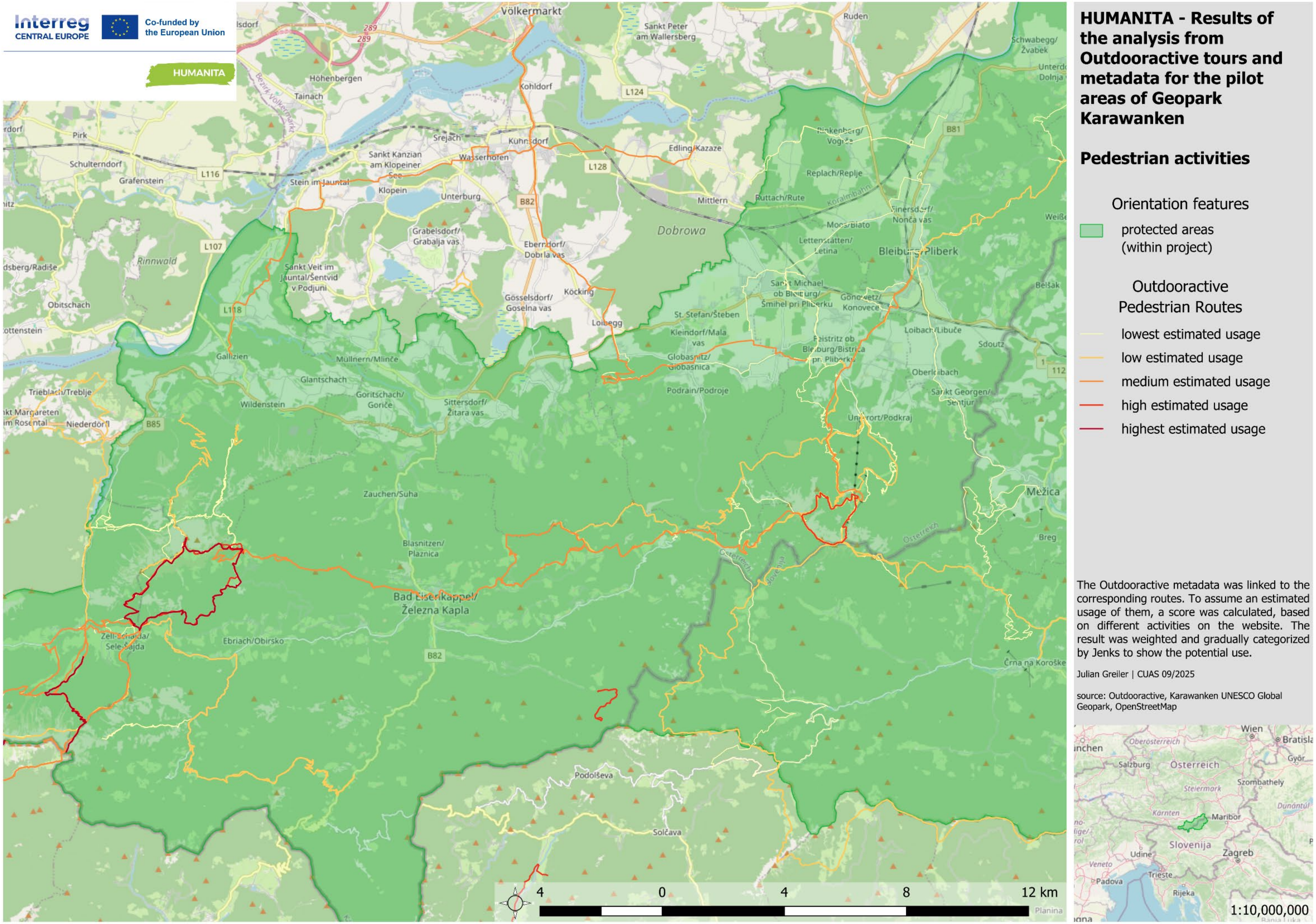


Figure 3 Karawanken UNESCO Global Geopark: Outdooractive estimated usage of Pedestrian routes.

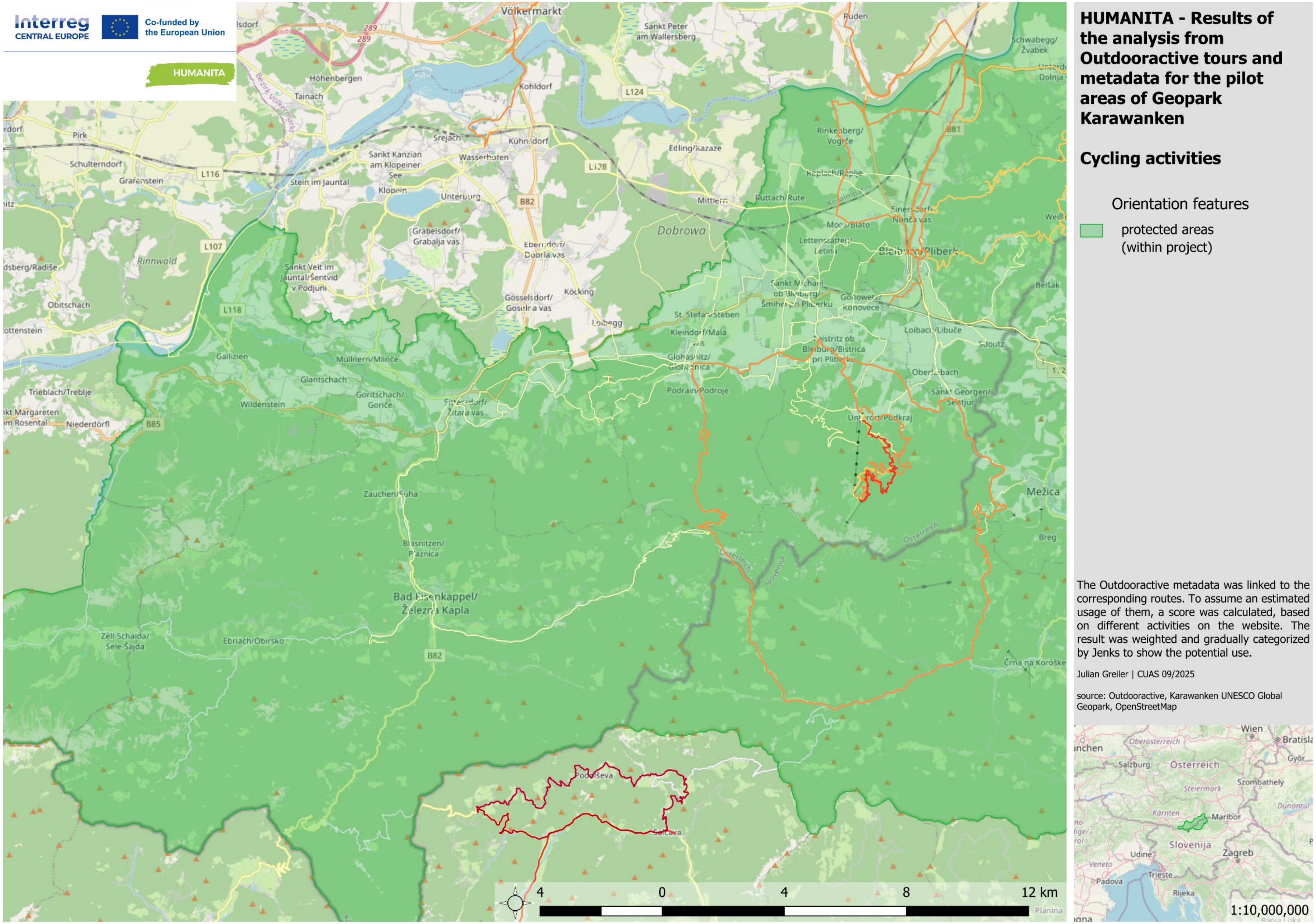


Figure 4 Karawanken UNESCO Global Geopark: Outdooractive estimated usage of Cycling routes.

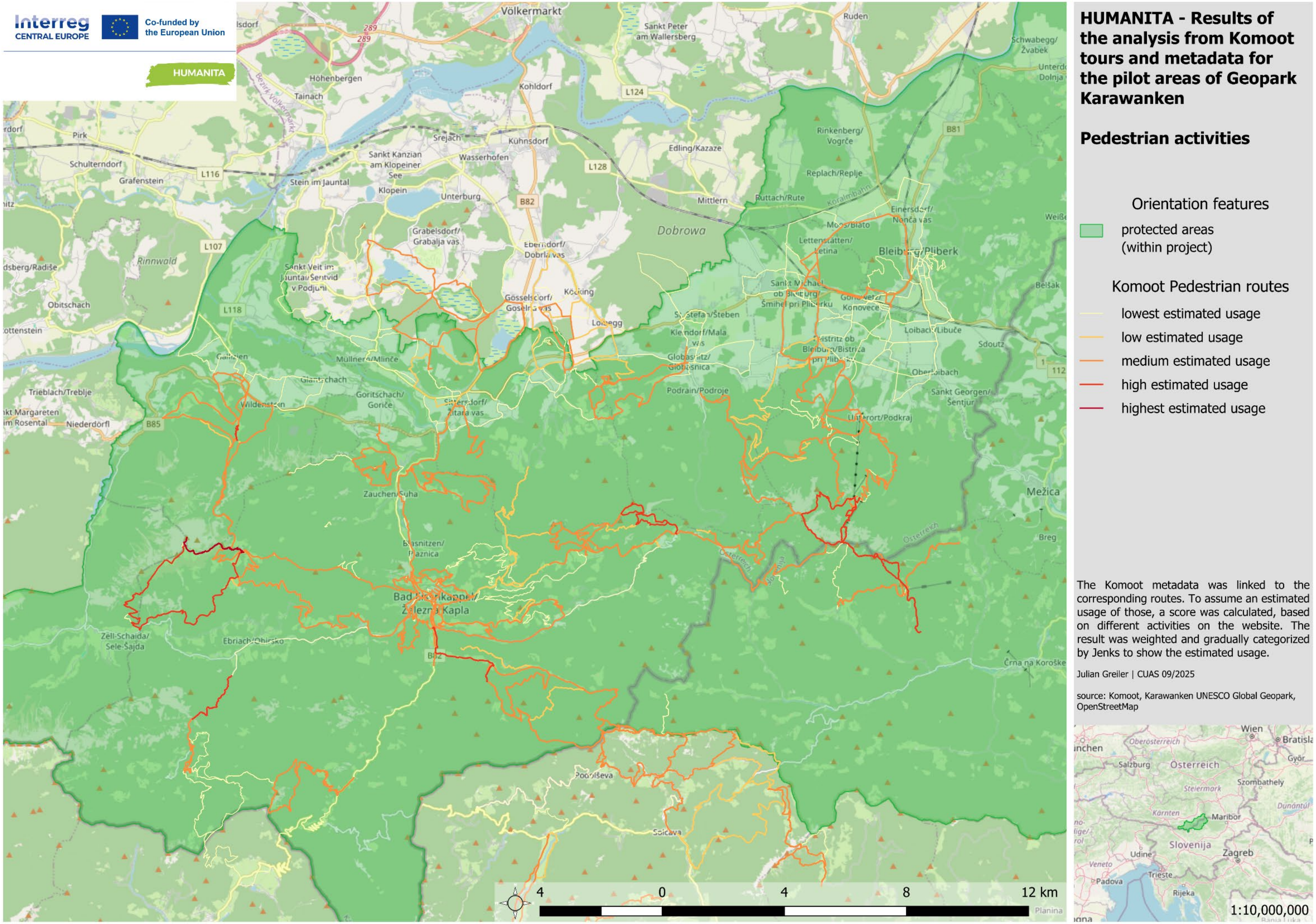


Figure 5 Karawanken UNESCO Global Geopark: Komoot estimated usage of Pedestrian routes.

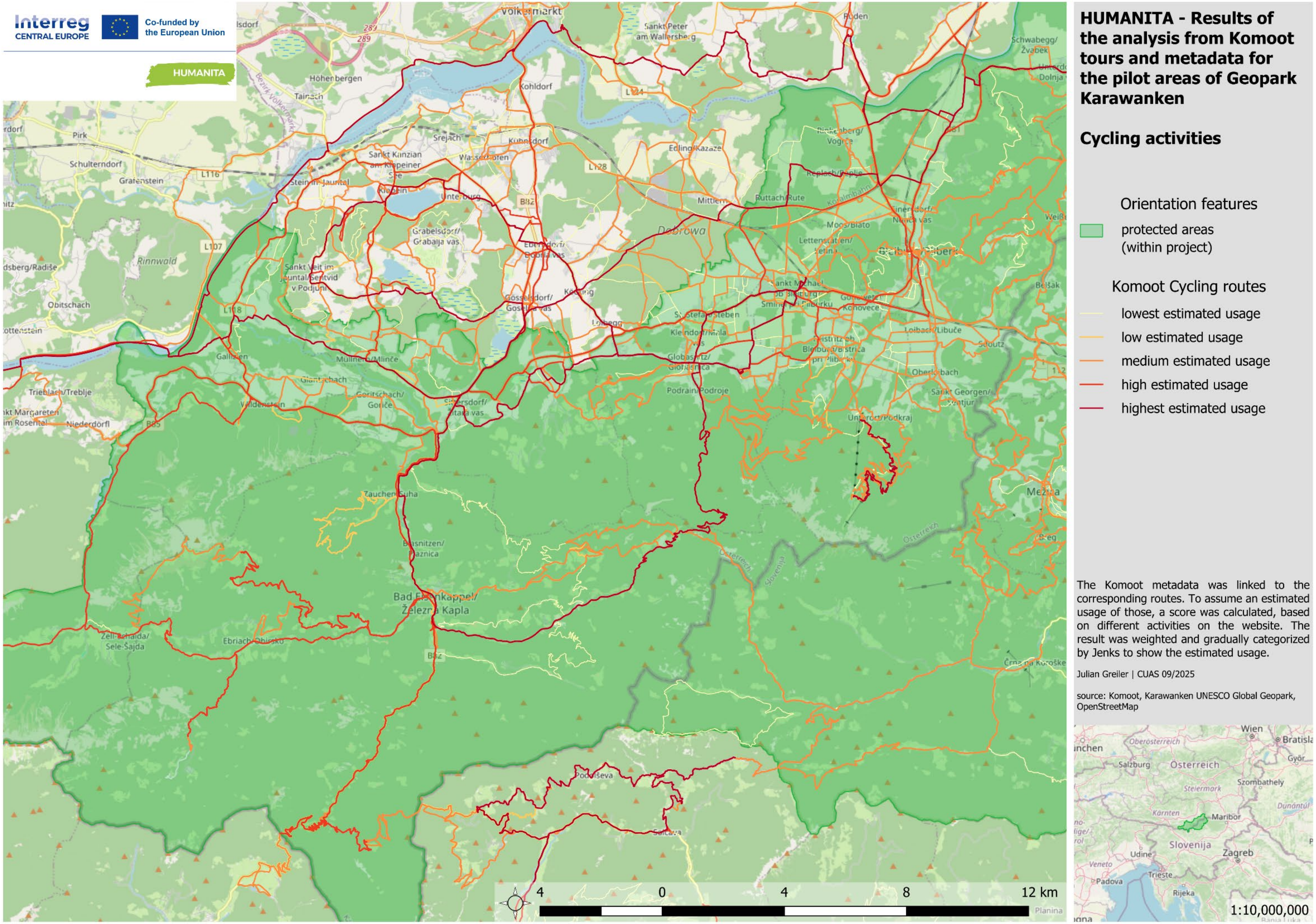


Figure 6 Karawanken UNESCO Global Geopark: Komoot estimated usage of Cycling routes.

Our pilot action **aimed to test solutions for protected area managers** in order to regulate information that is promoted on outdoor and fitness apps. The subsequent chapter summarizes the tested activities.

Komoot's tour planner and route suggestor **respects local restrictions and provides information about protected areas when tagged correctly on OSM:**

We added and updated **information about protected areas for all pilot sites on Open Street Map.** The boundary of Karawanken-Karavanke UNESCO Global Geopark was added to OSM on the 25th February 2025. Information about the park pops up if a highlight is selected within its boundaries.

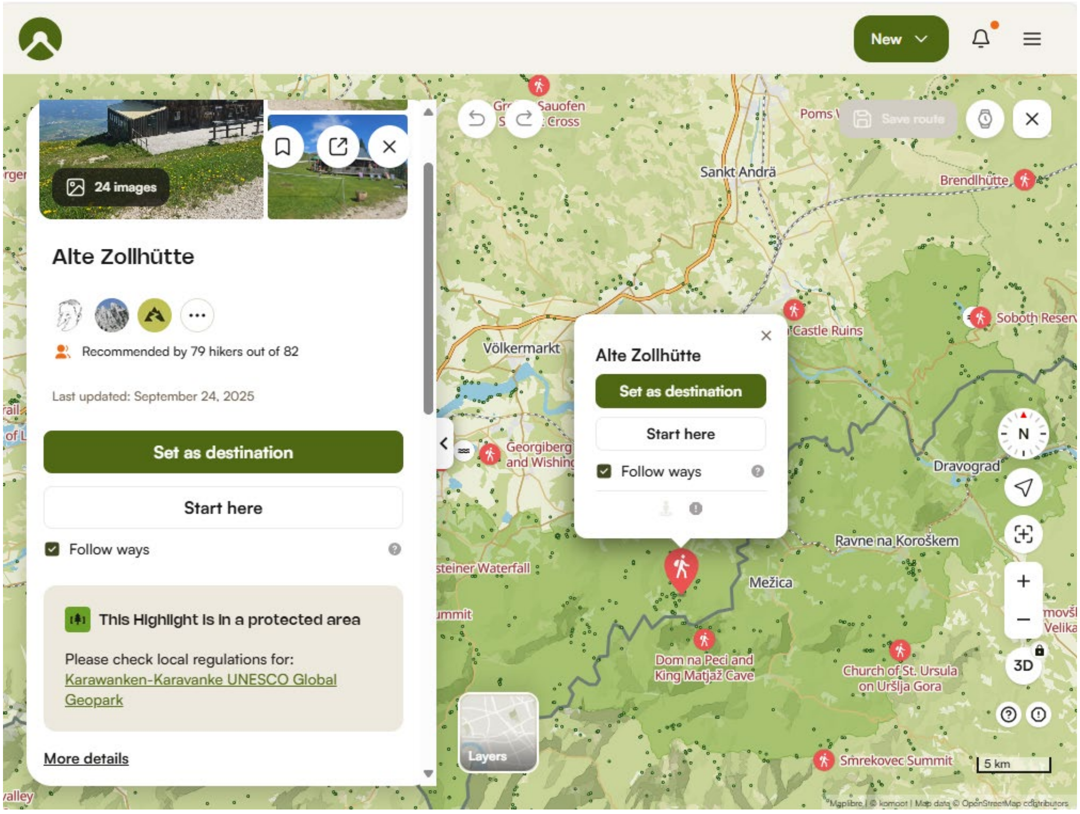


Figure 7: Information about local regulation within Karawanken-Karavanke UNESCO Global Geopark.

Komoot enforces r**estrictions** when route segments are tagged (i.e., access=no; bicycle=no, etc.). Users receive **warnings** alert users if their route may violate local rules. The tour suggestor will not generate any tours on tracks that have been tagged with restrictions. The restrictions have to comply with local regulations.

Ones changes have been made on Open Street Map it takes a couple of weeks until the information is updated on Komoot.

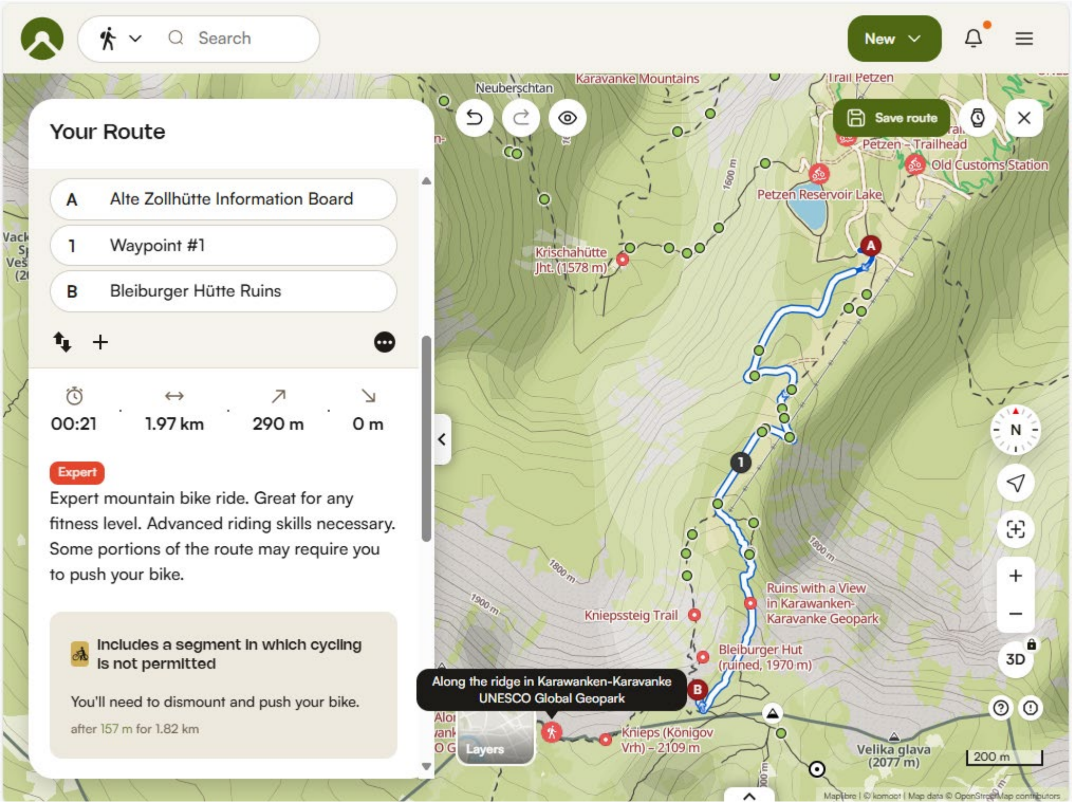


Figure 8: Information about access restrictions of paths within Karawanken-Karavanke UNESCO Global Geopark.

1.4. FUTURE DEVELOPMENTS

Currently we are **continuously working on the integration of data from Outdooractive, Komoot and Bergfex into our analysis.** The process of evaluation is still ongoing in the 6th period of HUMANITA project.

We are validating the completeness of the datasets which were downloaded in summer 2025 by student employees that supported HUMANITA project.

Bergfex data analysis is still ongoing. The combined layer showing the amount of promoted tours per trail is currently under preparation.

With the integration of all collected data into one GIS system which will be shared with all protected area partners, including the metadata of estimated trail use and metalink to the tours, partners can easily identify problematic areas and take action, where action is needed to inform visitors about potential conflicting zones.

To understand the representativity of fitness app data from Strava Metro a **comparison with data from automatic visitor counters is planned for other protected areas.** We started to compare **information about visitor frequencies from Strava Metro** with **automatic visitor counter data** from the bike park Petzen to see how much of actual visitor activity can be represented in the data and how well data from Strava Metro can predict actual visitor numbers. We are planning to compare data from Strava Metro with counter data from other pilot areas of our protected area partners in period 6.

VISITOR MONITORING: AUTOMATIC VISITOR COUNTERS (CUAS)

1.1. STARTING DATE

CUAS purchased three visitor counters from TRAFx and tested the functionality in the first period of the project. In May 2024 one of CUAS visitor counters was installed at the bike park Petzen/Peca, along the single trail Thriller. It is installed **along a segment where the University of Parma performs erosion monitoring.** One aim is to correlate the counter data with erosion data to estimate the erosion impact caused by mountain bikers along the trail.

Two of the counters were planned for the alpine zone of Hochobir, but unfortunately no permission from the ground owner could be reached. Instead, the counters served for educational purposes during HUMANITA summer school. One of them was installed at the Hochobir/Ojstrc pilot site along a popular hiking trail from Schaidasattel to Hochobir peak after the summer school in August 2025.

CUAS tested an algorithm for automatic counting of hikers, animals and vehicles (Microsoft Megadetector) on wildlife camera recordings was tested starting in July 2023. As our colleagues from university of Parma developed an algorithm that allows to process trail camera videos directly when partners upload their camera footage on the database, CUAS did not proceed with this activitiy.

1.2. METHODOLOGY DESCRIPTION

Data from automatic visitor counters allows the monitoring of visitor frequencies along selected trails. Depending on the location and type of technology used the counters vary in accuracy and consistency of data.

In the first period CUAS tested two counter technologies in an on-site field test at a popular mountain bike single trail in the region of Villach: TRAFx (TRAFx Research Ltd., Canmore, AB, Canada) Infrared Trail Counter, which is triggered by the infrared radiation emitted by people and animals that pass by, and TRAFx Vehicle Counter, which is a magnetometer that detects passing objects through sensing changes in the magnetic field. The infrared counter was also tested on a popular hiking trail.

Videos taken of the mountain bikers from behind with a wildlife camera (Patriot model, Browning Arms Co., Morgan, UT, USA) were manually evaluated and served as the “ground-truth” data of the experiment. Furthermore, these videos were evaluated with Microsoft Megadetector algorithm, which was customized for our purposes.

After a controlled field experiment at CUAS campus, in August 2023 the devices were installed alongside the trails for a duration of 28 days. The magnetometer was buried next to the trail in a plastic box (80 cm distance to the opposite trail side) and the infrared counter was positioned on a tree 1 m above the trail surface (1.5 m distance to the opposite trail side). The wildlife camera was installed longitudinally to the trail and recorded 5-second videos with a line of sight of around 10 m along the trail (Figure 1). The camera recorded cyclists from behind which avoided the identification of individuals.

From the 5th September – 12th September accuracy testing was carried out in Karawanken-Karavanke UNESCO Global Geopark at 4 counter locations: (1) Hiking Trail Petzen (below mountain lake), (2) Country Flow Trail Petzen, (3) Single Trail Thriller (Petzen), (4) Hiking Trail Schaida-Obir. For position (3) and (4) the evaluation is done and a correction factor is applied to counter data to improve the accuracy.

1.3. RESULTS AND OBSERVATIONS

When monitoring bikers, the **magnetometer undercounted 9.6%,** and the **infrared counter undercounted 32.8% of bikers** with an increasing undercount with higher visitor numbers. Regarding the average hourly counts of the test period, the highest visitor numbers were counted between 11:00 and 14:00. While the magnetometer only showed a slight undercount compared to the ground-truth data, the infrared counter showed the highest deviations during the afternoon hours.

A linear regression analysis was performed to calculate a correction factor for the visitor counters. The magnetometer model [$y = 0.978x - 0.286$ ($R^2 = 0.973$, $\sigma = 1.348$, $p < 0.001$)] can better predict the actual visitor numbers than the infrared counter model [$y = 0.774x - 0.491$ ($R^2 = 0.867$, $\sigma = 2.521$, $p < 0.001$)] (Figure 4).

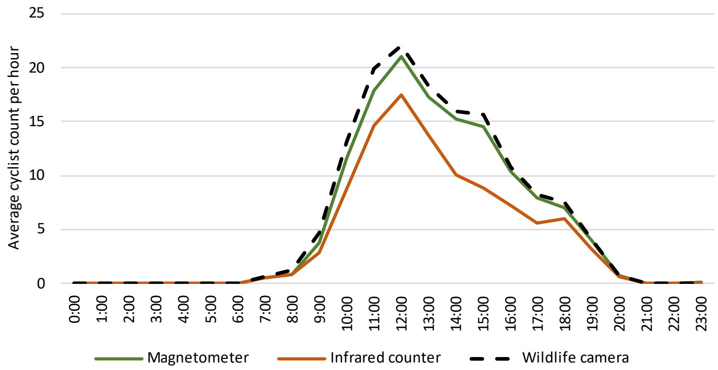


Figure 9 Average count of mountain bikers in the course of the day. The average hourly counts show a similar trend as the daily variations with highest undercounts around the highly frequented midday hours

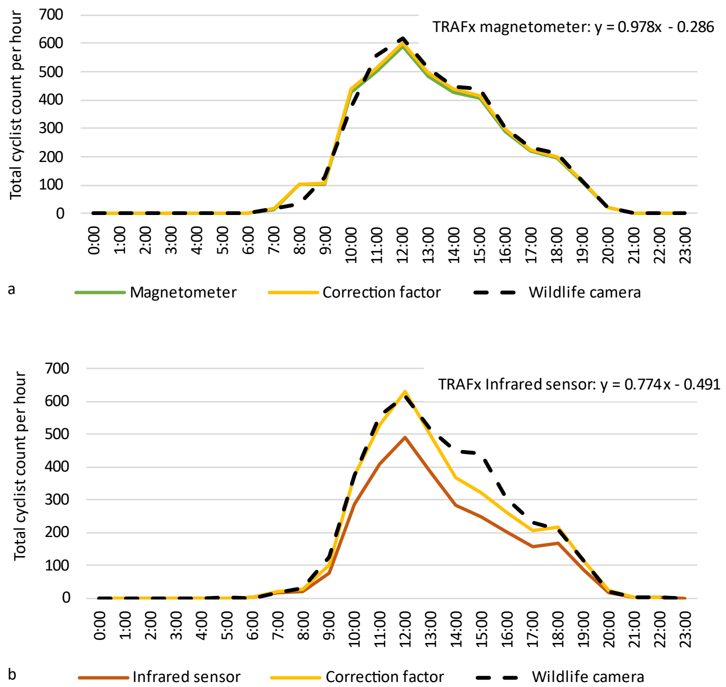


Figure 10 Total daily count of mountain bikers using the correction factor of the linear regression: for the magnetometer (a); for the infrared counter (b). The yellow lines represent the corrected hourly counts

1.3.1. Visitor Frequency - Petzen Bike Park - Single Trail Thriller Lower Part

Correction of accuracy

For the calculation of a correction factor all pairs of 0 counts from the wildlife camera and counter have been removed from the analysis. A linear regression analysis was performed:

$$y = -0.978 + 1{,}070 * counter \quad (R^2 = 0.897, \sigma = 1.361, p < 0.001)$$

In this regression, the variable *counter* represents a visitor counter value. If the value is **"0"** it **truly represents no visitors**. Since the intercept (-0.978) would imply that the trail receives a negative number of visitors when the counter is at 0, it has no meaningful interpretation in this context. Statistical testing also shows that the intercept is not significant.

For this reason, the intercept is excluded when applying the correction factor. Instead, the **correction factor relies solely on the slope coefficient (1.070)**, which describes how the counter values scale with the actual number of passes recorded.

The correction factor for the visitor counter is:

$$y = 1.070 \times counter$$

Presented visitor numbers are already corrected by the correction factor.

Between 1 September 2024 and 31 August 2025, a total of **3,730 passes were recorded along the Thriller trail segment** where our visitor counter is located. The highest activity was recorded from May through August, with additional use in autumn and limited activity beginning in March and April.

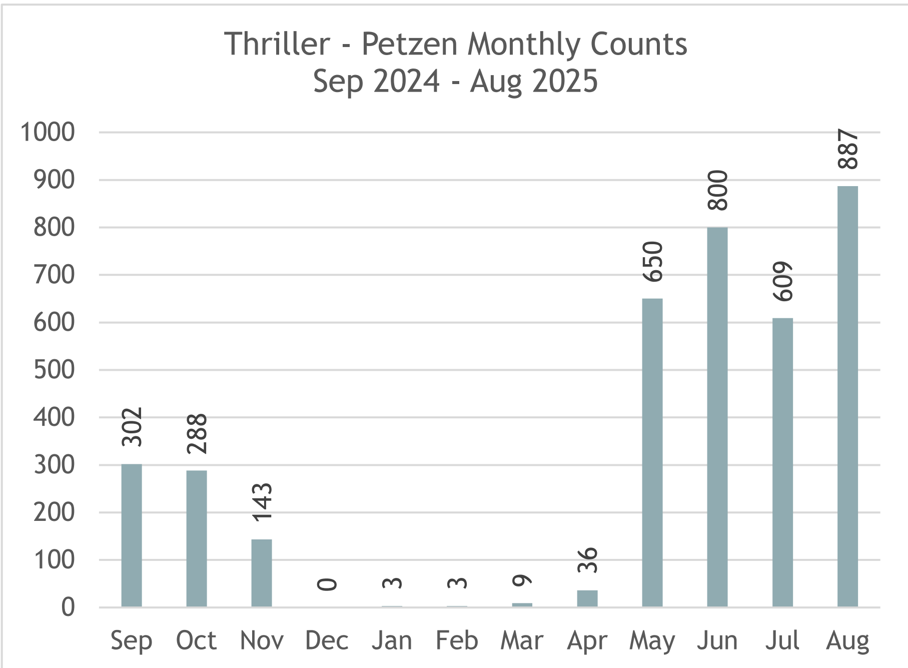


Figure 11 Thriller Trail - Total counts per month Sep 2024 – Aug 2025.

A comparison of the summer months (June–August) in 2024 (2,431 counts) and 2025 (2,296 counts) shows that trail use was slightly higher in 2024 (+135 people), despite June 2025 recording more visitors than June 2024. Weekly patterns indicate a clear concentration of activity on weekends. In the summer of 2024, for example, Saturdays averaged about 60 passes per day.

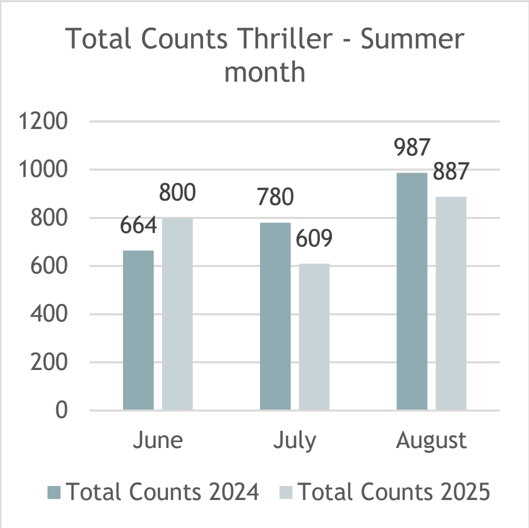


Figure 12 Total counts summer month 2024 and 2025.

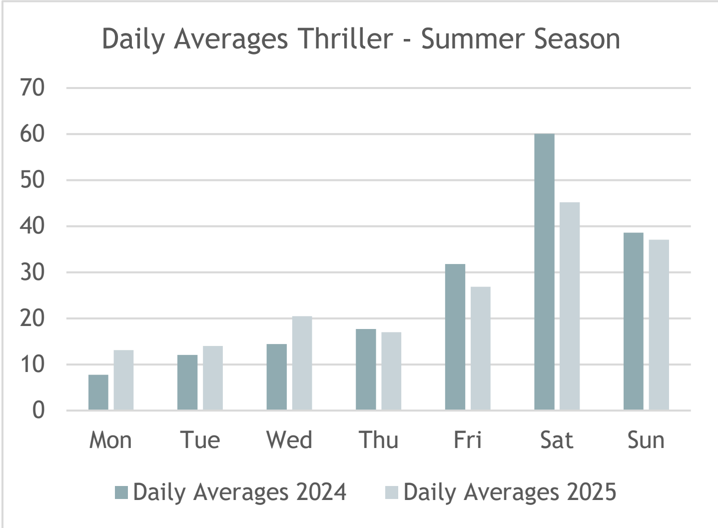


Figure 13 Daily average counts per weekday 2024 and 2025.

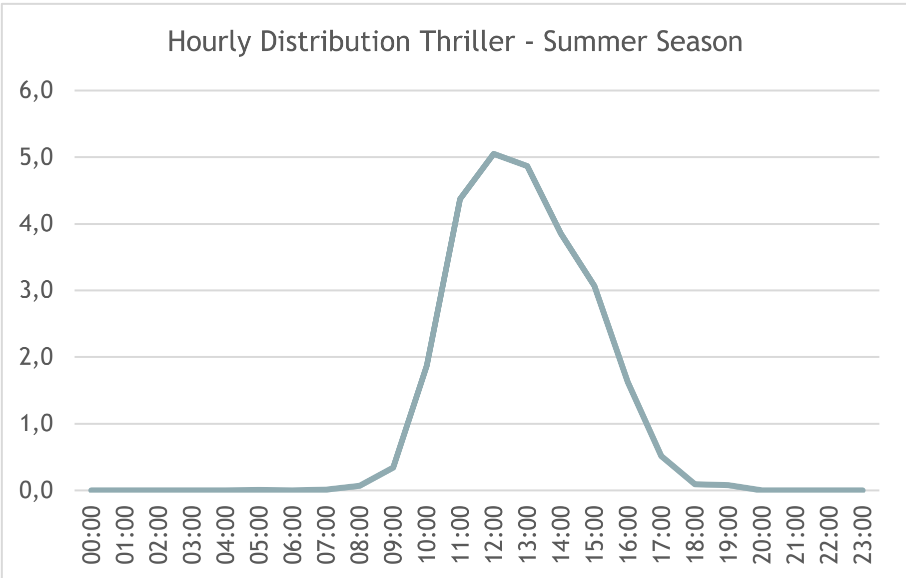


Figure 14: Hourly average counts in the summer month.

1.3.2. Visitor Frequency - Hochobir - Hiking Trail Schaida - Obir

The visitor counter on Hochobir was installed on the 26th August 2025. Date of the last data collection is the 13th September 2025.

In this period 472 pedestrians have been recorded.

Table 2: Total Counts of TRAFx counter at Hochobir hiking trail

Month	Total Count
Aug	219
Sep	253

The counter was tested for its functionality and we plan to continue the data collection in the upcoming period.

1.3.3. Comparison of automatic visitor counter data to Strava Metro data

For the Thriller counter, automatic visitor counts are available from May 9, 2024 onward. A comparison with monthly **STRAVA Metro data** was made for the period June 2024 to August 2025. During this time, the **STRAVA data represented on average 21,94% of the monthly counts** recorded by the automatic counter.

To estimate total visitor numbers from STRAVA data, an average **correction factor of 4.7 was applied.** This estimate is based on 10 paired data points (month with low frequencies Dez – May are not considered), which is a relatively short comparison period. The share of STRAVA counts ranged between a **minimum of 15.03%** and a **maximum of 30,69%** across the months considered. For other counters from Geopark Karawanken the time span of data collection with automatic visitor counters is too short to allow a comparison.

Table 3: Comparison between TRAFx Counter and Strava Metro.

2024	TRAFx Counter	Strava Metro	Factor	Percentage	Strava corrected
6	619	190	3,3	30,7%	619
7	732	110	6,7	15,0%	732
8	923	170	5,4	18,4%	923
9	283	70	4,0	24,7%	283
10	272	50	5,4	18,4%	272
11	133	25	5,3	18,8%	133
12	0	0	n.a.	n.a.	n.a.
	3539	**615**	**5,0**	**21,0%**	**2962**
2025					
1	3	0	n.a.	n.a.	n.a.
2	3	0	n.a.	n.a.	n.a.
3	9	0	n.a.	n.a.	n.a.
4	35	0	n.a.	n.a.	n.a.
5	609	125	4,9	20,5%	609
6	750	205	3,7	27,3%	750
7	567	125	4,5	22,0%	567
8	831	195	4,3	23,5%	831
	2986	**650**	**4,3**	**23,3%**	**2757**
Total	**6525**	**1265**	**4,7**		**5719**

1.4. FUTURE DEVELOPMENTS

Data collection with our visitor counters will continue.

VISITORS MONITORING: Automatic visitor counters (Geopark Karavanke)

2.1. STARTING DATE

In the project's initial phase, CUAS tested various visitor counter technologies. The focus was on testing technologies using infrared sensors and magnetometers. CUAS performed and presented the analysis of the testing and the results. None of the tested measuring devices or technologies was selected by Geopark Karawanken-Karavanke.

Main reasons: they do not provide automatic remote data downloads which poses a logistical issue when using 11 devices that are spread over large distances (combining devices with other projects, overall, 24 visitor counters in Geopark Karawanken-Karavanke). Additionally, manual data transfer does not provide immediate insight into the functioning of the devices, nor does it ensure real-time data transfer. Similarly, the tested devices do not offer data transfer to a specific website, where, with a single click, the user can simply view and analyse the data in real-time without delays.

The equation leads to the implementation of monitoring procedures. Geopark Karawanken-Karavanke is also conducting several testing phases through various Interreg projects to better understand different technologies, the accuracy of monitoring procedures, and the appropriateness of monitoring methods.

During the same period, CUAS also tested visitor counting using cameras (Wildlife cameras), but in the Geopark Karawanken-Karavanke, we excluded this method of visitor counting due to the controversial nature of 'video surveillance' and concerns about 'personal data' intrusion (filming in public places must be conducted under specific legal conditions – GDPR). We are using Wildlife cameras exclusively for observing wildlife near the trails and its surrounding areas to determine the presence and potential behaviour patterns of wildlife. We will not count animals (the timeline is too short to do the proper result of wildlife monitoring and long-term analysis). However, the wildlife cameras will be used for further observations and educational purposes.

In 2023, a tourist survey was conducted to identify the factors influencing tourists' behaviours, assess their prevalence and significance, and examine their potential to shape their attitudes toward sustainability and nature protection. From June 2023 to October 2024, trial monitoring activities were being carried out to improve methods and identify potential issues for further monitoring. The EGTC Geopark Karawanken-Karavanke has obtained all necessary permits from landowners and stakeholders to install visitor counters owned by Geopark Karawanken-Karavanke for the HUMANITA Project on both pilot sites (altogether 11 visitor counters + 20 Wildlife cameras for wildlife observation according to the implementation plan from 2023 (all owned by Geopark Karawanken-Karavanke – on Pilot site: Hochobir/Ojstrc we obtained permits for counter devices only owned by Geopark Karawanken-Karavanke, due to the restrictive requirements of the plot owners, no other devices could be used or installed at that Pilot site for the moment)).

However, individual permits have been obtained for the installation of a counter on Petzen/Peca for CUAS counter-bike trail, and an individual permit for Hochobir/Ojstrc was obtained by CUAS for the installation of a test position on Hochobir/Ojstrc as well.

Public procurement and purchase of equipment have been completed.

In 2024 three test devices were installed in the Petzen/Peca pilot site to establish functionality, acceptance among visitors, the quality, method and standard of installation of the construction of the devices, ratio and micro-locations, potential errors and quality of data and its transmission.

Rapid test analyses of the operation of the test devices were carried out at the site of the installation of the test devices. 2-hour comparison (manual counting vs automatic counting from visitor counters) helped to adapt devices immediately. Adjustment of offsets, distance, construction, orientation and terrain adjustment with micro-location gave an acceptable result with a two-hour comparison between manual and automatic counting on the spot. Before the adjustment, the first test showed some minor errors, which were adapted to the terrain and situation with the adjustment. The second test shows no major errors that affect the accuracy of counting, which is also expected in the future. Since the testing area of the counters was on the bike trail, most errors related to the speed of the bikers, which we adjusted by moving devices to slower locations at that point for further testing. With the help of the provider of visitor counters, we upgraded (free of charge) some of the devices to avoid future errors and selection of the fast-passing locations.

Automatic data transfer is functioning as expected using NB-IoT and Satellite logs and we anticipate no differences in other locations. The data is transferred to the dedicated website (Dashboard) in real-time, where there are immediate insight and basic analysis of the data according to availability and need.

One tested position was removed during the winter 2024/2025, as planned, because the road is transformed into a ski slope during that season, making it unsafe to leave the equipment there (and was reinstalled at the beginning of the summer season).

In 2025 we changed two testing counters with upgrade versions (bike trails for high-speed detections). We also installed all 11 positions. 6 positions are covered in pilot site Petzen/Peca and 5 positions are covered the pilot site Hochobir/Ojstrc. There were some adjustments of the locations from the original implementation plan (2023) due the complications with the owners and obtained permits. However, all directions are now covered and in function. Additionally, one counter from CUAS is installed in Petzen/Peca pilot site, and one in Hochobir/Ojstrc pilot site.

2.2. Errors, mistakes and problems:

Some issues with getting **permits** from plot owners caused slight adjustments to the position implementation plan. These changes do not impact the final monitoring results, only the anticipated timeline for installations.

Five positions were vandalised by persons/hikers and were reinstalled in their spots. Two positions were "attacked" by cows (one position was already reinstalled/hardened, and one position needed to be slightly relocated (30 meters) in a short period of time to avoid potential further conflicts with cows). One position did not work as predicted (low data collection and troubles with signal) – several test positions were conducted until the data collection was satisfactory.

One counter was damaged on the spot and replaced with a new one (with the combination of data-collection).

Numerous tests were conducted to determine the accuracy of individual locations in obtaining the number of transitions. Through these tests, a correction formula will also be developed when analysing the obtained data.

2.3. METHODOLOGY DESCRIPTION

The purpose of monitoring the pilot sites of Petzen/Peca Mountain and Hochobir/Ojstrc is to establish a system for assessing the capacity of tourism in these areas. The objective is to assist local planners, stakeholders, and park managers in understanding how visitor numbers fluctuate within a protected area, quantifying the detrimental impact on environmentally sensitive areas, and ensuring an equitable distribution of environmental impact from visitors. Our investment is aimed at supporting the trial of new monitoring methods and approaches to managing visitor traffic, as well as implementing further measures through action plans.

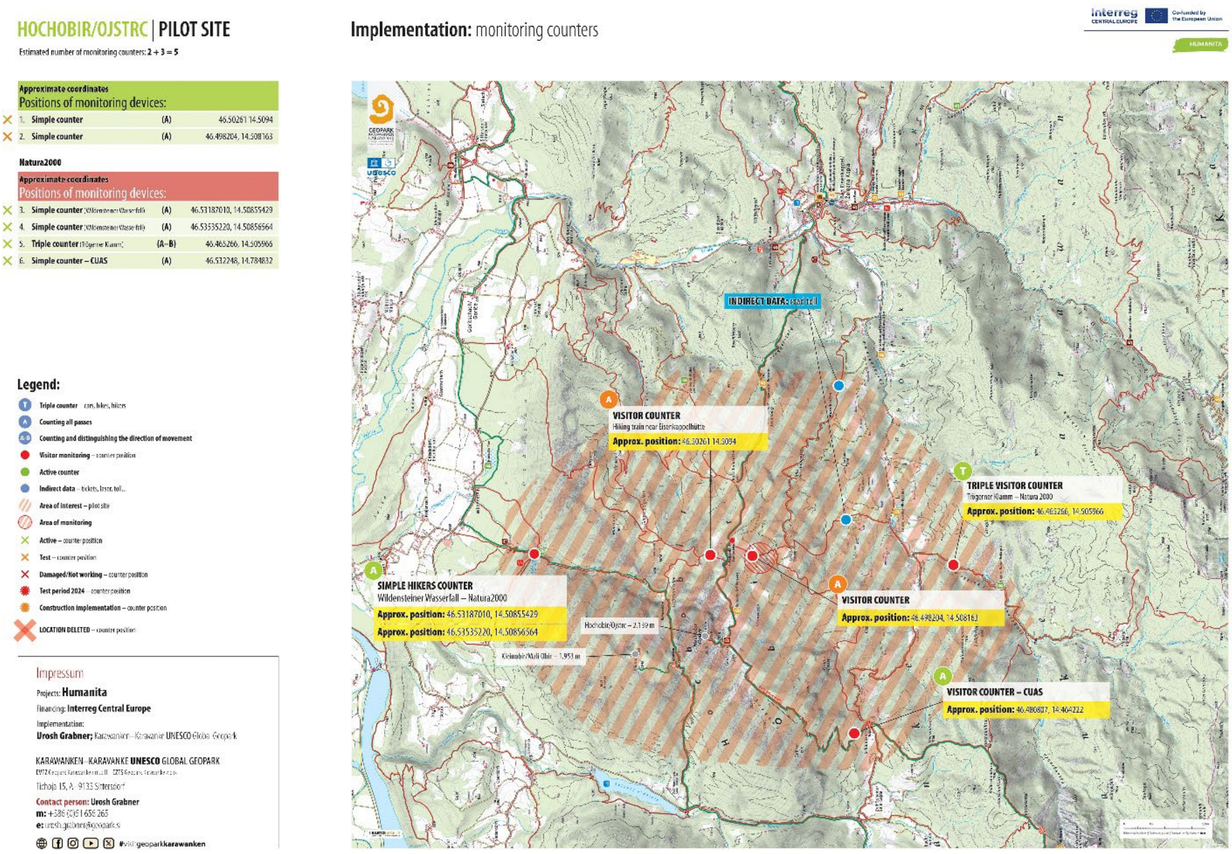


Figure 15 Implementation plan Hochobir/Ojstrc.

11 visitor counters with supporting software and direct download in real-time, including 2 triple visitor counters and 9 simple visitor counters (some with indicators of direction), are strategically installed on the locations covering access and descent on and from vulnerable areas. Additionally, two counters from CUAS are installed on both pilot sites. We utalize indirect data such as tickets and toll fees collected over the past 5 years and in the future from the pilot sites (cable car on Petzen/Peca and toll fees on road to mountain huts on Hochobir/Ojstrc), for comparative data between automatic counter monitoring and tourist and local activities at highlights in protected areas.

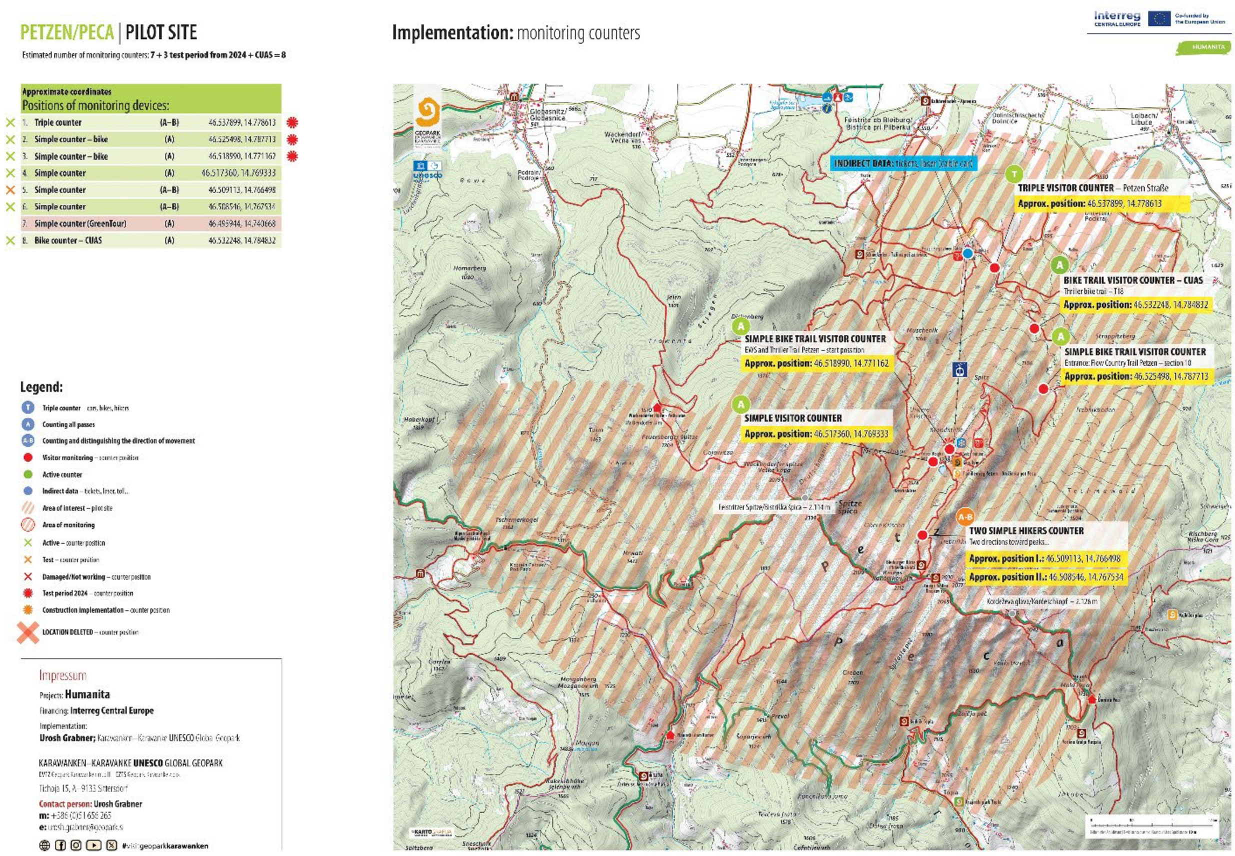


Figure 16 Implementation plan Petzen/Peca

2.4. RESULTS AND OBSERVATIONS

The data has been collected from all position of visitor counters at the Pilot site on Petzen/Peca Mountain and Hochobir/Ojstrc. This includes the number of cars, bikers, and hikers recorded by the triple visitor counter for the time of the testing period and beyond. The counters are now fully operational and will stay on positions till further, the only one which will be removed from the spot in the middle of November before the winter season is the Triple counter on Petzen Straße. This is to avoid accidents and potential damage to the devices, as the position coincides with the use of the ski area and expands in the winter season. The collection of useful data begins after the final testing period of the 2025 summer season, starting with the installation of most counters in March 2025 – testing period at all available implementation positions in both Pilot sites.

The first test, before the adjustment, showed some minor errors, which were adapted to the terrain and situation with different correction approaches (correction/alignment of device position, minor change of location, relocation, change of measurement angle or distance, etc...). Additional tests were conducted to eliminate initial problems and the need for a maximum baseline for monitoring at each location.

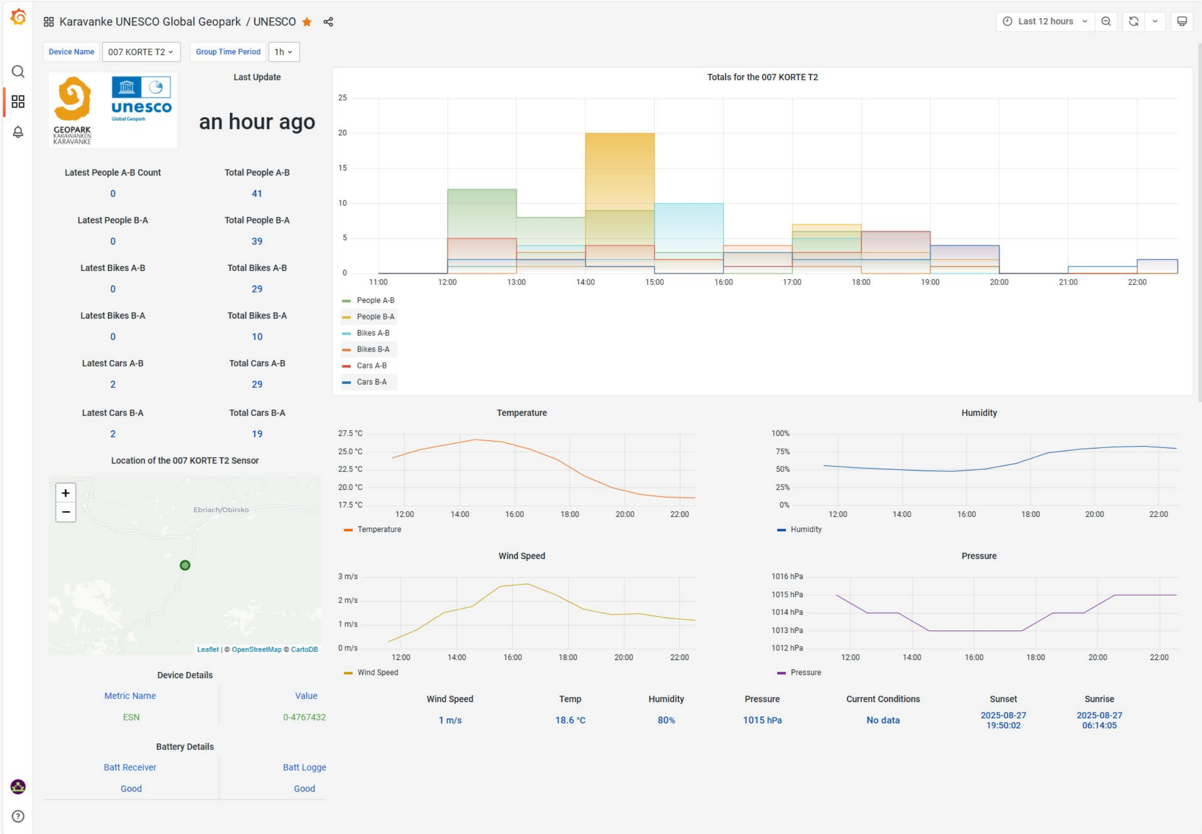


Figure 17 Sample of data collection from triple counter – Dashboard

Careful location monitoring has played a major role in improving accuracy, making successful adjustments, and reducing errors. Automatic data transfers not only cover the number of passes but are also crucial in identifying the operation of each counter position. Signal strength, battery status, and regular or irregular data transfers are indicators that illustrate the timely resolution of problems in the field – reaction time to manage the problems when they occur is essential for good results.

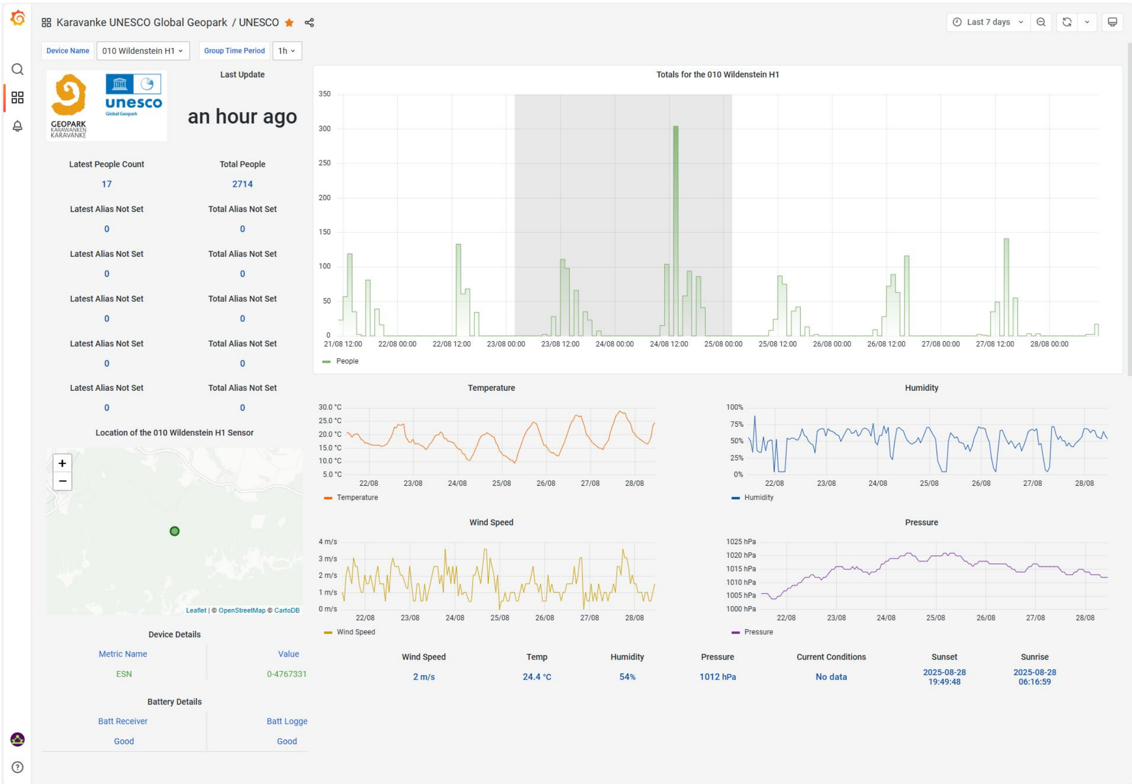


Figure 18 Sample of data collection from simple counter – Dashboard

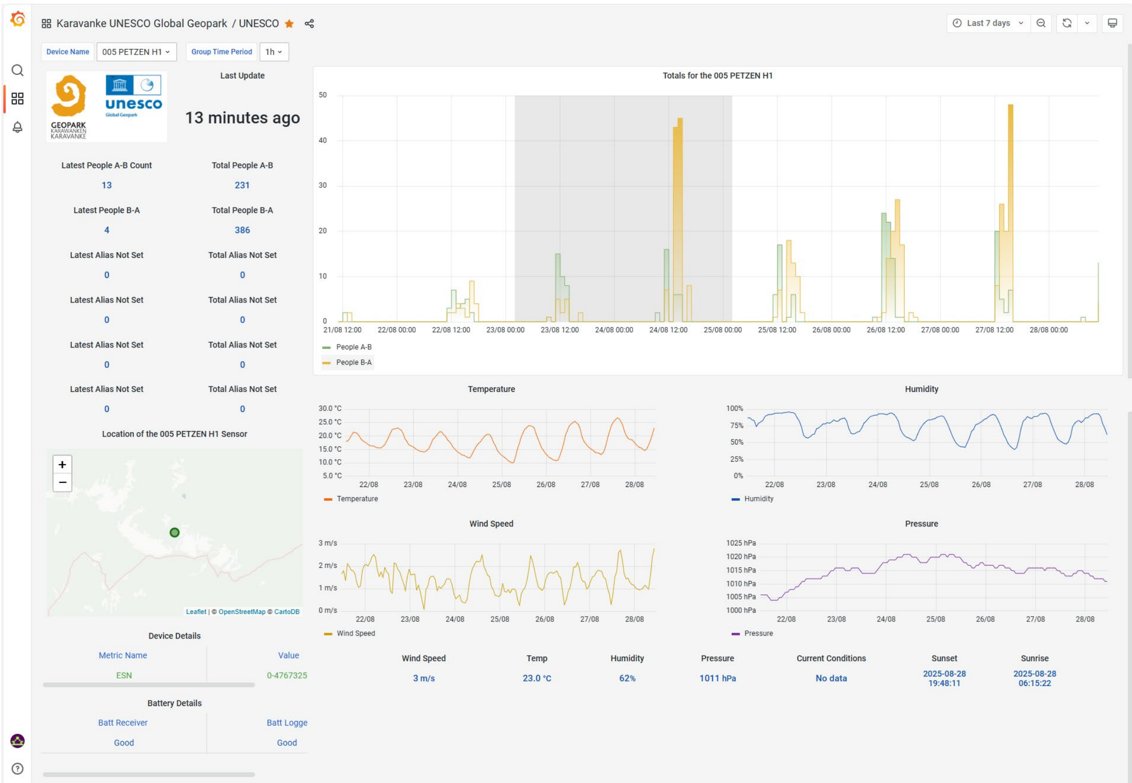


Figure 19 Sample of data collection from simple counter with directions – Dashboard

2.5. Errors, mistakes and problems:

No major problems were detected during secondary testing, and all adaptations of the test equipment were adjusted to the position at the time of installation. All devices were checked and tested by the manufacturer before delivery. Minor errors due to the position of the device are corrected on an ongoing basis in accordance with the operation and short on-site comparative manual tests.

Main mistakes/troubles:

- Poor signal (solution: adjust location to clear sky, away from obstacles).
- Vandalism (solution: reinstallation/strengthening the foundations).
- Damages of the counter (solution: counter replacement)
- Bad data collection receiver (solution: adjust the length of measurement, as narrow as it could be, change the position of the counter).

The installation requires a minor intervention in the environment by placing the two wooden poles at a suitable distance from each other (from max. 4 to max. 6 meters – depending on the device). **Recommendation:** as narrow as it can be (simple counters up to 2,5 meters, triple counters up to 4 meters for maximal effect). The poles must be well-braced and in line to trap the signal between the transmitter and receiver. The counters consist of two units which connect. In our case, this requires careful choice of position (mountains, low ground, stone base) so that the structure can be fixed in the ground (ground depth of at least half a metre for a good-fixed installation).

2.6. FUTURE DEVELOPMENTS

The installation of all devices was carried out in the summer of 2025. We have three tested positions, two of which have undergone minimal adjustments to improve results (upgrade to the speed-counting). Alongside these, we have installed a total of 11 visitor counters—two high-speed counters for bikers, two triple counters and seven additional counters across both pilot sites. All these counters are owned by Geopark Karawanken-Karavanke.

The devices will remain active even after the project concludes. Some positions may be adjusted for enhanced data collection, which will be determined through careful analysis, comparison with indirect data, and established rapid tests to recalculate the accuracy of each counter's position for better results.

The connectivity of all visitor counters from the three projects will be implemented, creating a network of about 22 visitor counters covering passages to and from vulnerable and sensitive areas within and at the boundary positions of the Geopark.

Recommendations:
For monitoring purposes (selection of the devices for our needs), it is necessary to carefully select positions that allow a 50-metre radius for the devices to be placed (considering terrain, ground, signal, strategic position, permits). The positions must be checked for signal strength and coverage for automatic data transmission. Satellite coverage is 99%; however, obstacles in the position can interfere with the signal – clear access to the sky is crucial. NB-IoT signal coverage is usually mapped by the provider and gives a clear picture of the strength of the signal. However, the same approach should be followed as with a satellite

signal. The stronger the signal, the better the data capture and transmission – testing the position with a temporary installation is desired for a better result.

In our case, the devices are not camouflaged and are publicly visible (even if we didn't expect vandalism, it happened).
Recommendation for this is to place the devices in obvious public places to avoid individual approaches of unnecessary damage to them. The devices are also placed in areas where activity is only during the day (in plain sight). The construction should be solid and as stable as possible to withstand unnecessary and unwanted contact with participants.

Otherwise, it is recommended to camouflage the devices and the eventual structure and location.

Coordination with the manufacturer is also strongly recommended for resolving problems or errors.
Clearly define the objectives and purpose of the measuring devices to create meaningful results.
Clearly define what the transitions are at the positions of the measuring devices:

- Do you count only pedestrians or a combination with other participants?
- Is it a calm, slow pass or a fast pass, e.g. bikers downhill can go up to 80 km/h downhill?
- In the case of a combination with car counting or car/biker/pedestrian combination, it is equally important whether it is a calm route with low vehicle speeds or a road with a speed limit of 90 km/h.
- Do you need data collection for the directions of the passes, or is there only one direction or no need for direction?

The measuring devices/counters should be adapted to all characteristics of the monitoring spots and the needs for successful data collection.

Recommendations/Notice about the installation positions:

- **Read and follow the instructions from the manufacturer!**
- **Choose open sky position** (better signal, better data-collection, ...).
- **Clean the area** (no high grass, no branches and no moving parts within a few meters that can interfere with the counter).
- **Stable fundaments and construction** (ensuring unwanted movements/interference with positions by hikers or natural elements).
- **Narrow passage** (The pedestrian counting passage should be wide enough to allow only one person to pass through. This will avoid errors when counting the passage of multiple overlapping people – recommendation up to 2 meters for hikers, up to 3 meters for bikers, and up to 4 meters for cars).
- **Avoid** pastures (unwanted interference with animals – especially cows), steep slopes, proximity to elements such as electrical wiring or electrical boxes, structures that emit magnetic fields, high vibrations into the environment or create micro movements of the ground (example: cable cars, snow canons, high-performance water pumps, heavy equipment, etc). **Avoid all elements that can physically influence on the devices.**
- **Test the position** (do the rapid test to establish accuracy of the position for the counter – compare analogue data with digital data for the decent period).
- **Move the counter if you got bad result** (sometimes couple of meters already helps to improve the functions).
- **Monitor the counter positions regularly** for unwanted errors, so you can react as soon as possible.

VEGETATION MONITORING: eDNA Analysis (CUAS)

3.1. STARTING DATE

Test sampling was performed on 27th July 2023 at the Petzen/Peca pilot site. For this purpose, standard sampling kits were used for sample collection and CUAS trainees collected the samples in the field.

On 19. July 2024 sampling was repeated at Petzen/Peca. Test kits were handed out to visitors and collected in the afternoon. On 10th July 2024 in the frame of the introductory workshop, workshop participants and HUMANTIA project partners were asked to sample their shoe soles.

3.2. METHODOLOGY DESCRIPTION

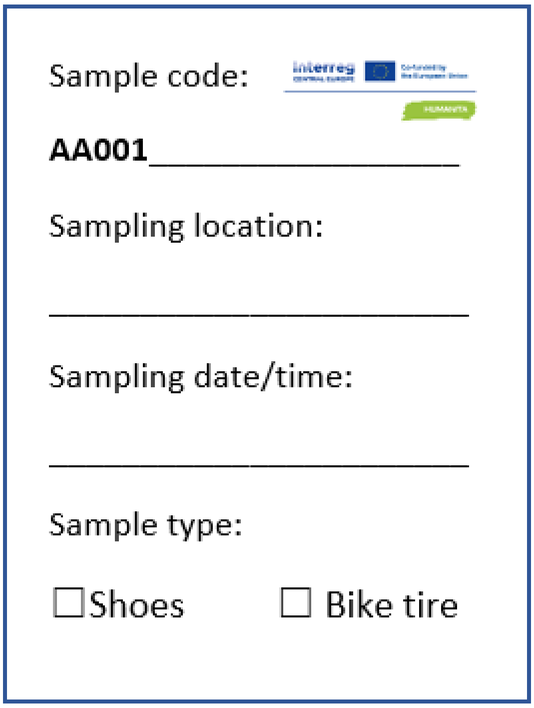
In this study, the application of environmental DNA (eDNA) collection and analysis as a tool for detecting invasive plant species in soil samples to trace the dispersal of pollen and seeds of non-native and potentially invasive plant species was conducted. The samples were collected from different sources including paths, shoes, and bikes within the Karawanken/Karavanke Geopark, the Petzen ski area and along hiking trails. Certain species that are known to be more common in the area were in focus of the study and include **Canadian goldenrod (*Solidago canadensis*), glandular balsam (*Impatiens glandulifera*), and Erigeron annuus, known as annual fleabane.** Detection of the **Japanese knotweed (*Falopia japonica*)** was tested as well. These species are of particular concern due to their potential for widespread dispersal and dramatic changes of habitats in which they occur. They may outcompete native flora, disrupt local ecosystems, and alter habitat structures, leading to a decline in biodiversity.

Canadian goldenrod is known for its ability to dominate landscapes, often overshadowing native plants and limiting their access to essential resources such as sunlight and nutrients. **Glandular balsam**, thriving in wet environments, poses a threat to riparian zones by displacing native aquatic plants and affecting the wildlife that relies on these habitats**. Annual fleabane** spreads rapidly along ruderal areas, including trails and bike paths. It may reduce the possibilities for growth of native species.

To detect these, a specially designed eDNA sampling method was developed for the project. eDNA method provides a sensitive and non-invasive means of detecting these invasive species by analyzing soil samples for their genetic material. This approach offers several advantages over traditional survey methods, including the ability to identify low-density populations that may otherwise go unnoticed. Furthermore, by strategically sampling along tourist infrastructure, such as hiking trails and bike parks, the study aims to **map the distribution of invasive species and understand their dispersal patterns in relation to human activity.**

Sampling Kit

A sampling was designed and constructed by the CUAS which consisted of a recyclable bag, single use gloves, a spatula, a tube with sampling code for the collected sample, a label on which the information on sample location, time and date could be entered, and a sheet with a description of the project Humanita. The kits were used for **collecting samples along the hiking and biking trails by CUAS staff and by citizens in the area to collect soil samples** from paths, bikes, and shoes.


Sample code:

AA001__________________

Sampling location:

____

Sampling date/time:

____

Sample type:

☐Shoes ☐ Bike tire

Figure 20 A label used by citizens/CUAS staff to write information about samples they collected.

The following protocol was prepared for sampling soil from diverse substrates:

»In the project INTERREG CE project HUMANITA, the UNESCO Chair on sustainable Management of Conservation Areas from the Carinthia University of Applied Sciences in Villach is studying various aspects of impacts of tourism on protected areas. One of potential threats to protected areas are non-native and invasive plant species. To assess the contribution of visitors to the dispersal of such plants, soil from shoes and tires of visitors in protected areas will be collected and analysed using novel environmental DNA (eDNA) analysis. eDNA from the collected soil will be analysed to specifically detect the presence of invasive and non-native plant species in the studied areas.

Equipment:

- A bag with sample tube
- Protective gloves
- A bag containing spatula
- Label
- Sampling instructions

Procedure:

- Make sure you work clean and safe using the provided tools
- Identify a surface on your shoe soles, bike tires, that contains some soil or identify non-native plant species along the path
- Open the sampling kit bag and put on the gloves
- Take the spatula and the tube out of the bag and open the tube
- Using spatula, fill up the tube up to ¾ with the material from the shoe, wheel, or path
- Close the tube and store it in the small bag
- Fill out the label (sampling date, precise location, sample type, and your email in case you want to be informed about analyses results) and store it together with the tube
- Dispose the tube with label in the cooling box at the bike rental at the valley entrance of the cable car
- Dispose the leftower materials – safeguard the environment by recycling the materials used!«

Figure 21 Sampling with the sampling kit prepared by the UNESCO Chair for Humanita Project

eDNA extraction

During the soil sampling phase, a sterile spatula was used to collect approximately 1-2 gram of soil from bike tires, shoe soles, or soil from the ground along the hiking or biking path into a sterile DNA-free 5 mL Eppendorf tube. From the path, two samples were collected at each sampling point. Sampling from the ground was usually carried out from 3 locations in the direct vicinity at 0-20 cm on either side of the path. The samples were taken to the depth of 0-3 cm. The samples were stored in a cooling box at 0-4 °C and at the end of the day transported to the laboratory and stored at -20 °C until extraction.

An aligoté of 500 mg of each sample were transferred into a sterile 2 mL collection tube with ceramic beads, provided in the NucleoSpin Soil kit by Macherey-Nagel (Düren, DE). To the tube, 700 µL of the lysis buffer (Buffer SL1) was added, followed by the addition of 150 µL of proteinase Enchancer SX. Samples were vortexed for 5 min and centrifuged. The next steps were carried out according to the protocol of the kit including precipitation of the contaminates and with SL3 and centrifugation, transfer of the lysate to the spin column for inhibitor removal, filtration of the lysate, adjusting of biding condition using buffer SB, transfer to another spin column, binding of the DNA, 4 washing steps, drying of the membrane, and elution in 80 µL of elution buffer.

DNA extracts were quality and quantity checked by a gel electrophoresis and Quantus device, respectively.

In total, including negative extraction controls, 76 DNA Extracts was included in the further analysis

Metabarcoding and data analysis

In the previous phase of the analysis, the sensitivity of the method for detection of environmental samples was tested using plant extract and soil extract from the base of the plants in the field.

In the current analysis, metabarcoding analysis was performed by the company Sinsoma GmbH and is summarized in their report. The following information was included:

The client sent 76 DNA extracts for metabarcoding for the molecular identification of the plants in the samples. Specific in-house validated primers1 were used for their identification. These target ITS2 (nuclear) and, based on experience, are well suited to distinguishing the species of this group of organisms. All generated DNA sequences were bioinformatically processed, compared with those in publicly available sequence databases (GenBank® NCBI), and assigned to the species/taxa accordingly. In metabarcoding, reliable detection of the DNA of a species or taxon is defined as detection of DNA sequences that match 99% with those of this species in the databases and that also make up at least 10% of the generated DNA sequences in the respective sample. DNA sequences with a low number (n < 25) or with a match below 99% are considered "uncertain" detection. For these species, we recommend a targeted follow-up search using more sensitive methods (qPCR, CE-PCR) if necessary. All species with < 95% agreement were excluded. 1 Primers can be used to determine the specific DNA segment that is amplified in the PCR. Metabarcoding uses general primers for an entire group of organisms (e.g., plants).

The outcome of metabarcoding were analyzed and visualized in R. The **European Alien Species Information Network (EASIN) database was accessed via its web interface or API**. The search was focused on alien species reported in specific countries of interest: Austria, Slovenia, Hungary, Czech Republic, and Germany. The search was filtered to include species categorized as alien or invasive. Taxonomic group of plants was selected. The data was downloaded in a tabular format (CSV) from EASIN, including information on species name. The species names in the EASIN dataset were matched with the species names in Humanita dataset, listed and counted.

3.3. RESULTS AND OBSERVATIONS

Test of detection

In a test run three of four targeted non-native species were detected using metabarcoding approach. In test samples from plants and soil, **DNA from Canadian goldenrod (*Solidago canadensis*), Himalayan balsam (*Impatiens glandulifera*), and Annual fleabane (*Erigeron annuus*)** were found (Fig. 3). The amplification of the DNA from plant tissue and soil of Japanese knotweed (*Reynoutria japonica*) was not successful. Thus, we assume that this species cannot be reliably detected using the proposed approach.

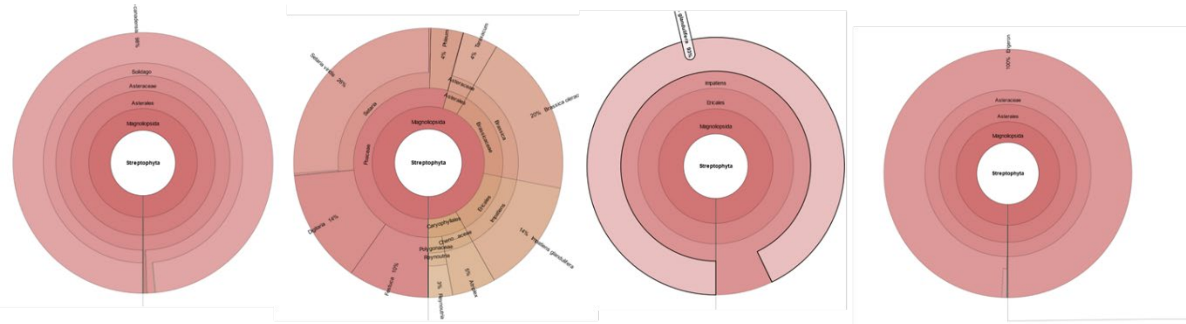


Figure 22 The Crona Chart on representation of reads in different plant tissue samples (leafs), representing Canadian goldenrod (Solidago canadensis), Japanese knotweed (Reynoutria japonica), Himalayan balsam (Impatiens glandulifera), and Annual fleabane (Erigeron annuus).

In July 2024 sampling was repeated at the pilot Site Petzen. Figure 23 shows the locations of collected samples by citizen scientists as well as by scientists within the area. Other samples were collected during the introductory workshop at Geo.Dom Petzen.

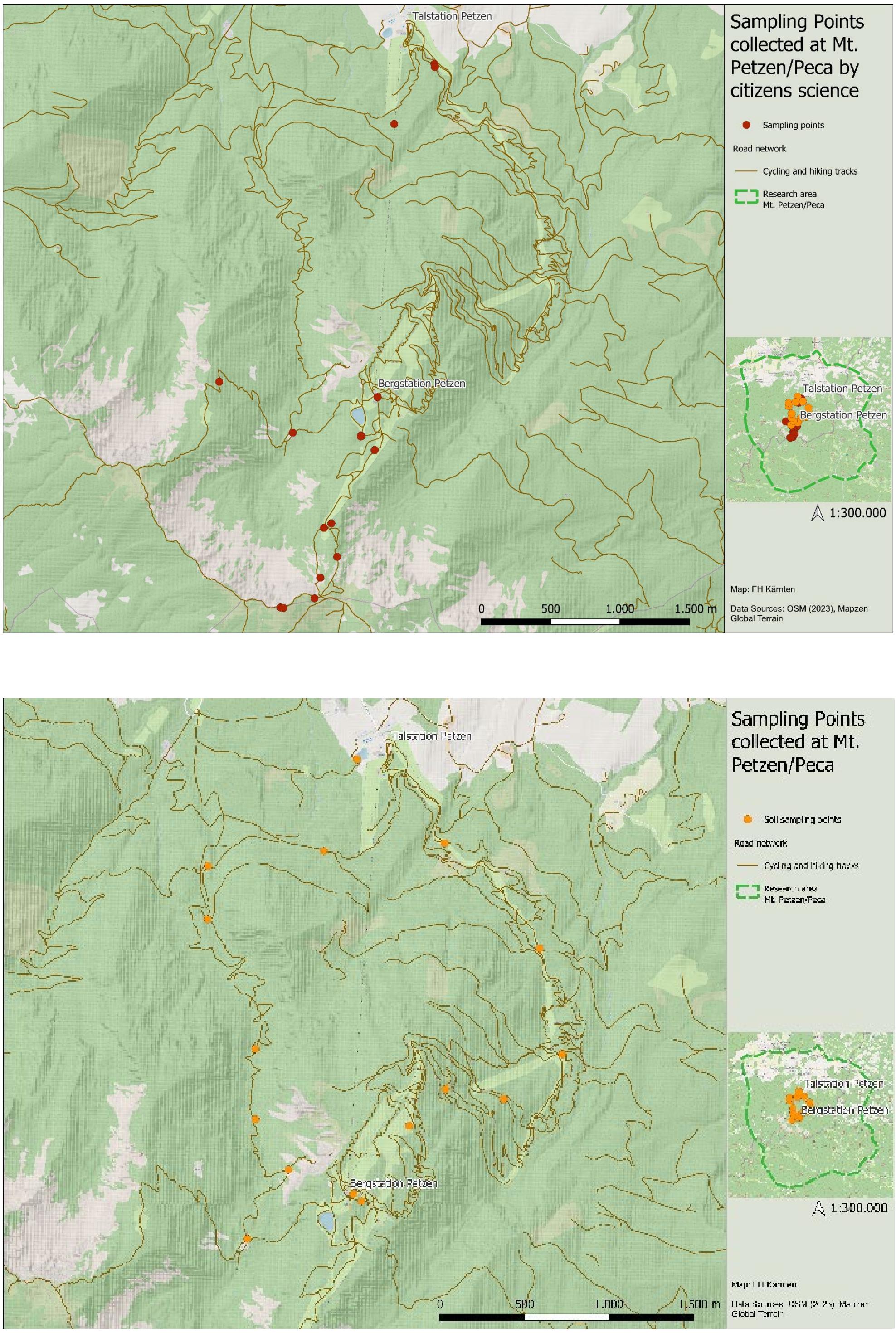


Figure 23: Locations of collected samples by citizen scientists (upper figure, red dotts) and scientists paths (lower figure, orange dotts) along in the area of Geopark.

From 76 analyzed extracts, Metabarcoding generated readable DNA sequences for almost all samples. Most samples were collected from the path (35) while more than 10 were collected from Shoes and Soil. Four negative controls were included as well and one single plant sample was collected by citizens (Fig. 5).

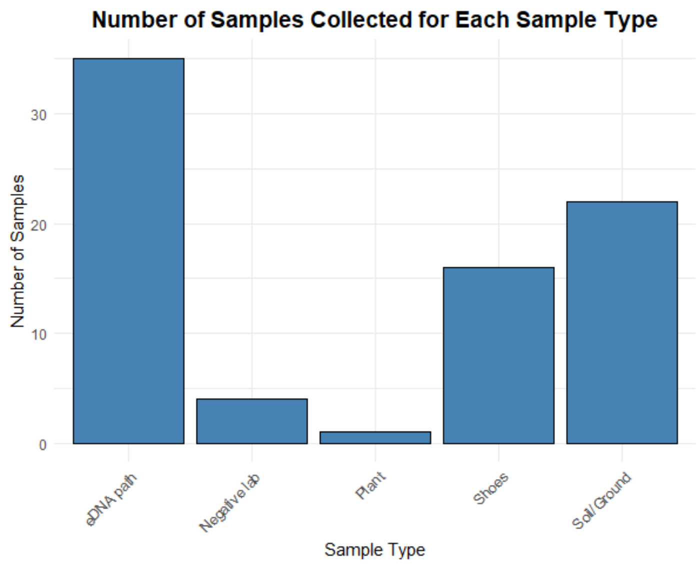


Figure 24 Number of samples collected for different sample types included in DNA analysis.

No plant sequences were detected for the following samples: AA038, AA083, AA098, and AA099, as well as NC02 and NC03, the latter two presumably being negative controls provided by the customer. On average, on average between 118 - 173 DNA molecules were detected per sample, with the fewest in AA035 (n=136) and the most in AA041 (n=260,470). These DNA sequences could be assigned to an average of 45 taxa per sample, or **approximately 34 species** (Fig.) 7. Sample AA055 contained the highest number of detected species, with 157 taxa and 127 species, while three species were detected in samples AA067, AA095, and AA110, and only one species was detected in sample AA035, *Primula minima*. Representatives of a total of 55 plant families were identified, with the majority of taxa belonging to the grass family. The most frequently identified species were *Plantago sp.* (50 records), *Leontodon hispidus*, and *Festuca rubra*, each with 44 records, as well as *Urtica dioica*, a stinging nettle, with 41 records.

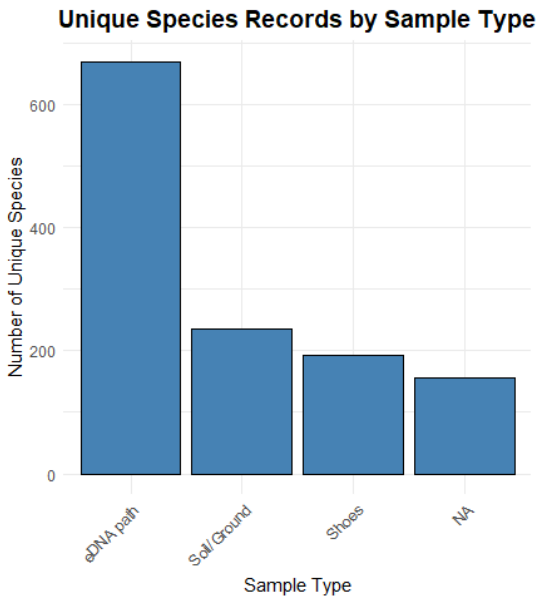


Figure 25 Number of all taxa detected in different sample types.

Table 4 Comparison of significance using a Wilcoxon non-parametric test for the number of detected species per sample among each sample types.

	.y.	group1	group2	p	p.adj	p.format	p.signif	method
1	num_unique_species	Shoes	Soil/Ground	0.00322	0.016	0.00322	**	Wilcoxon
2	num_unique_species	Shoes	eDNA path	0.000810	0.0049	0.00081	***	Wilcoxon
3	num_unique_species	Shoes	Plant	0.184	0.47	0.18430	ns	Wilcoxon
4	num_unique_species	Soil/Ground	eDNA path	0.271	0.47	0.27058	ns	Wilcoxon
5	num_unique_species	Soil/Ground	Plant	0.116	0.47	0.11644	ns	Wilcoxon
6	num_unique_species	eDNA path	Plant	0.126	0.47	0.12564	ns	Wilcoxon

In samples collected by CUAS staff along two selected path between the top and valley station of Petzen, most taxa were detected (over 600). From the citizens samples from soil and shoes, for each category about 200 taxa were detected.

Most taxa were, however, found in shoes **with over 50 taxa per sample,** which lets us assume that shoes can significantly contribute to the dispersal of plant material within and between different regions.

Around 25 taxa per sampling effort were found in path and soil samples collected by citizens (Fig. 7).

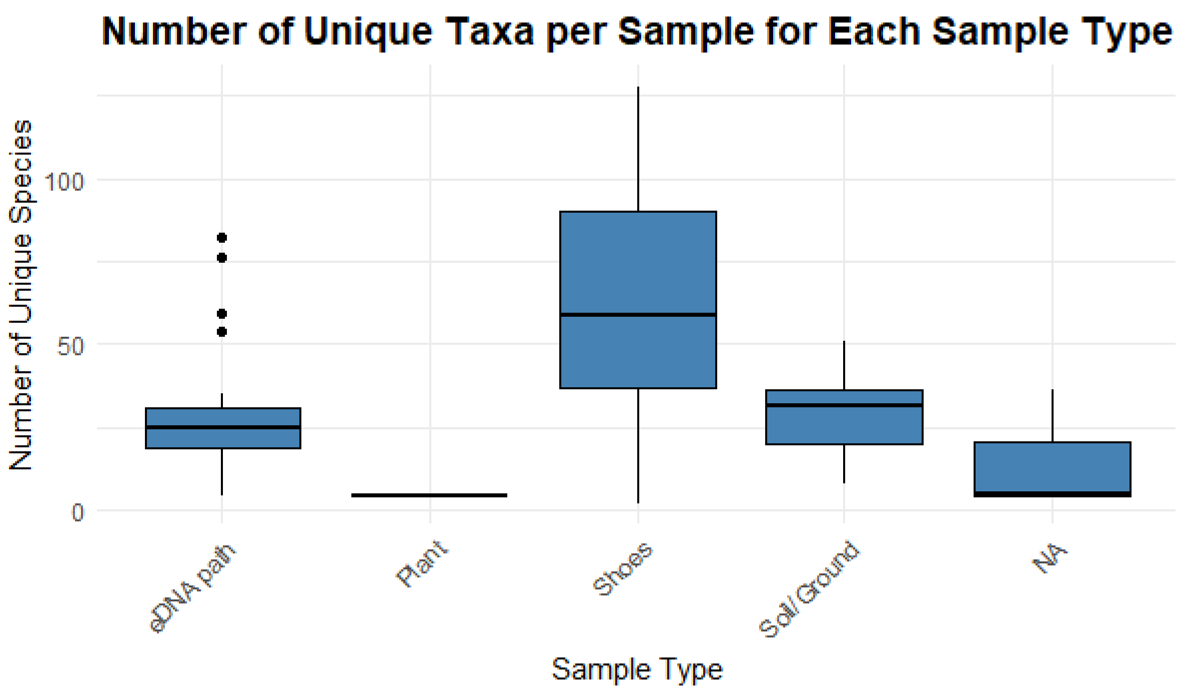


Figure 26 A boxplot comparison of detected number of unique species per sample for each type of sample.

Most species found across diverse samples were taxa not including invasive species, with common taxa *Plantago sp*. being found in over 50 samples, and other common species grass red fescue (*Festuca rubra*), rough hawkbit (*Leontodon hispidus*), and stinging nettle (*Urtica dioica*) with over 40 records (Fig. 8). Other 6 species comprise common taxa generally distributed in the area.

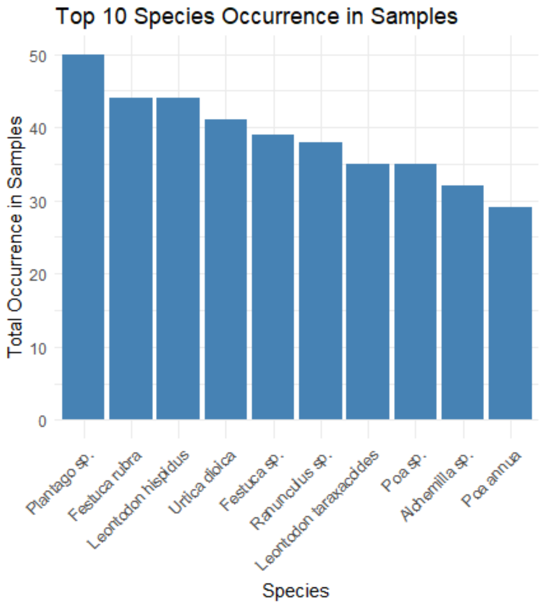


Figure 27 Bar chart representing ten most frequently detected plant taxa in the area of Geopark Karawanken/Karavanke.

In regard to non-native species, five species were detected in total (Tab. 2). Among these are two of the target species tested in the initial phase of the experiment, including **annual fleabane (*Erigeron annuus*) and Himalayan balsam (*Impatiens glandulifera*).** Other species include **black locust (*Robinia pseudoacacia*), Canadian fleabane (*Erigeron canadensis*), small balsam (*Impatiens parviflora*), and common ragweed (*Ambrosia artemisiifolia*).**

In total, they were found in twelve of 72 samples. Six of these samples originate from the sampled paths, six detections were made from hiking shoes.

There were also **some taxa detected, that may include non-native and invasive species (e.g., hogweed (*Heracleum sp*.).** However, due to sequence resolution, these recordes can only be distinguished to the genus level and not resolved at the species level. Thus, it is unclear if it is the in the area local and widespread common hogweed (*Heracleum* sphondyllium) or the invasive giant hogweed (*Heracleum* mantegazzianum) of which species DNA was detected.

Table 5 List of detected species with Percent ID and Number of Sequences detected.

Sample	Family	Genus	Species	Percent ID	Number Sequences	Proportion Sequences
AA040	Asteraceae	Erigeron	*Erigeron canadensis*	99,44	1723	1,58
AA040	Asteraceae	Erigeron	*Erigeron annuus*	99,74	1164	1,06

AA053	Balsaminaceae	Impatiens	*Impatiens glandulifera*	99,54	650	0,97
AA056	Balsaminaceae	Impatiens	*Impatiens glandulifera*	100	71	0,03
AA061	Asteraceae	Ambrosia	*Ambrosia artemisiifolia*	99,76	127	0,09
AA061	Balsaminaceae	Impatiens	*Impatiens glandulifera*	100	6	0
AA062	Balsaminaceae	Impatiens	*Impatiens parviflora*	100	10	0,01
AA070	Asteraceae	Ambrosia	*Ambrosia artemisiifolia*	100	6	0
AA072	Fabaceae	Robinia	*Robinia pseudoacacia*	100	7	0
AA076	Asteraceae	Ambrosia	*Ambrosia artemisiifolia*	99,58	14	0,01
AA084	Balsaminaceae	Impatiens	*Impatiens glandulifera*	100	11	0,01
AA100	Asteraceae	Erigeron	*Erigeron canadensis*	99,03	104	0,05
AA106	Balsaminaceae	Impatiens	*Impatiens parviflora*	99,47	15171	10,15
AA106	Asteraceae	Erigeron	*Erigeron annuus*	99,47	7904	5,29
AA106	Balsaminaceae	Impatiens	*Impatiens glandulifera*	99,38	30	0,02
AA109	Asteraceae	Erigeron	*Erigeron annuus*	98,97	147	0,11

VEGETATION MONITORING: Citizen Science (Invasive Alien Plant Species) - iNaturalist (CUAS and Geopark Karawanken-Karavanke)

4.1. STARTING DATE

The iNaturalist project, initiated in December 2023, aims to gather information and observations on Invasive Alien Species (IAS) in Geopark Karawanken-Karavanke.

During this period, project promotion activities were carried out on an individual level by inviting the most active observers on iNaturalist in Slovenia and Austria and locations in and close near areas Geopark Karawanken-Karavanke (all together 40 invitations, which shows lack of activities of observers in our area - from that we gain approx 20 observations). Additionally, were invited 10 highly active amateur naturalists in the region (with no big interest to get involved). In July 2024 the Citizen Science platform “Österreich forscht” included the project on their list (no effects were noticed in the iNaturalist project). The project was promoted on several occasions (workshops, seminars, introductions...) in ten months (without the contribution of Geopark Karawanken–Karavanke members), we collected 121 observations of IAS in the whole region of Geopark Karawanken-Karavanke, only 50 were observed in 2024 all other observations are older (This is not the result to be expected from highly recommended iNaturalist App - promoted with 3,8 MIO observers worldwide). The activity of Geopark Karawanken-Karavanke raised the observation to 4.017 (one member of Geopark Karawanken-Karavanke observed and marked almost 3.900 observations from 2023 - 2024). All data was downloaded and will be presented in separate approach.

4.2. METHODOLOGY DESCRIPTION

- **Participation**: Involving the population as citizen scientists who collect data on the occurrence and spread of invasive species.
- **Training and Workshops**: Providing online educational materials and workshops to equip participants with the necessary knowledge and skills to identify and report invasive species.
    - Online Green Academy
    - Workshops
    - Summer School (2025)
- **Data Platform**: Using the iNaturalist platform to record the locations of plant species. The collected data is validated there and then analyzed and published by the Carinthia University of Applied Sciences (UNESCO Chair for Sustainable Management of Protected Areas).

4.2.1. Project Goals:

- **Monitoring/observation and Early Detection**: Establishing a network to monitor invasive species in the Karawanken-Karavanke UNESCO Global Geopark to detect their spread at an early stage.
- **Awareness-Raising and Education**: Informing and involving the population about the importance and impact of invasive alien species and the influence of climate change and human activities on their spread.
- **Data Collection and Analysis**: Collecting and analysing data on the occurrence and spread of invasive species by citizen scientists.
- **Management and Control**: Developing an action plan to control and contain invasive species to protect native ecosystems.

4.3. RESULTS AND OBSERVATIONS

Invasive Plants monitoring/observation project on the iNaturalist with regular updates on the project journal (see communication report).

Invasive plants in view project description on platform “Österreich forscht”: [Invasive Plants in View - Österreich forscht]

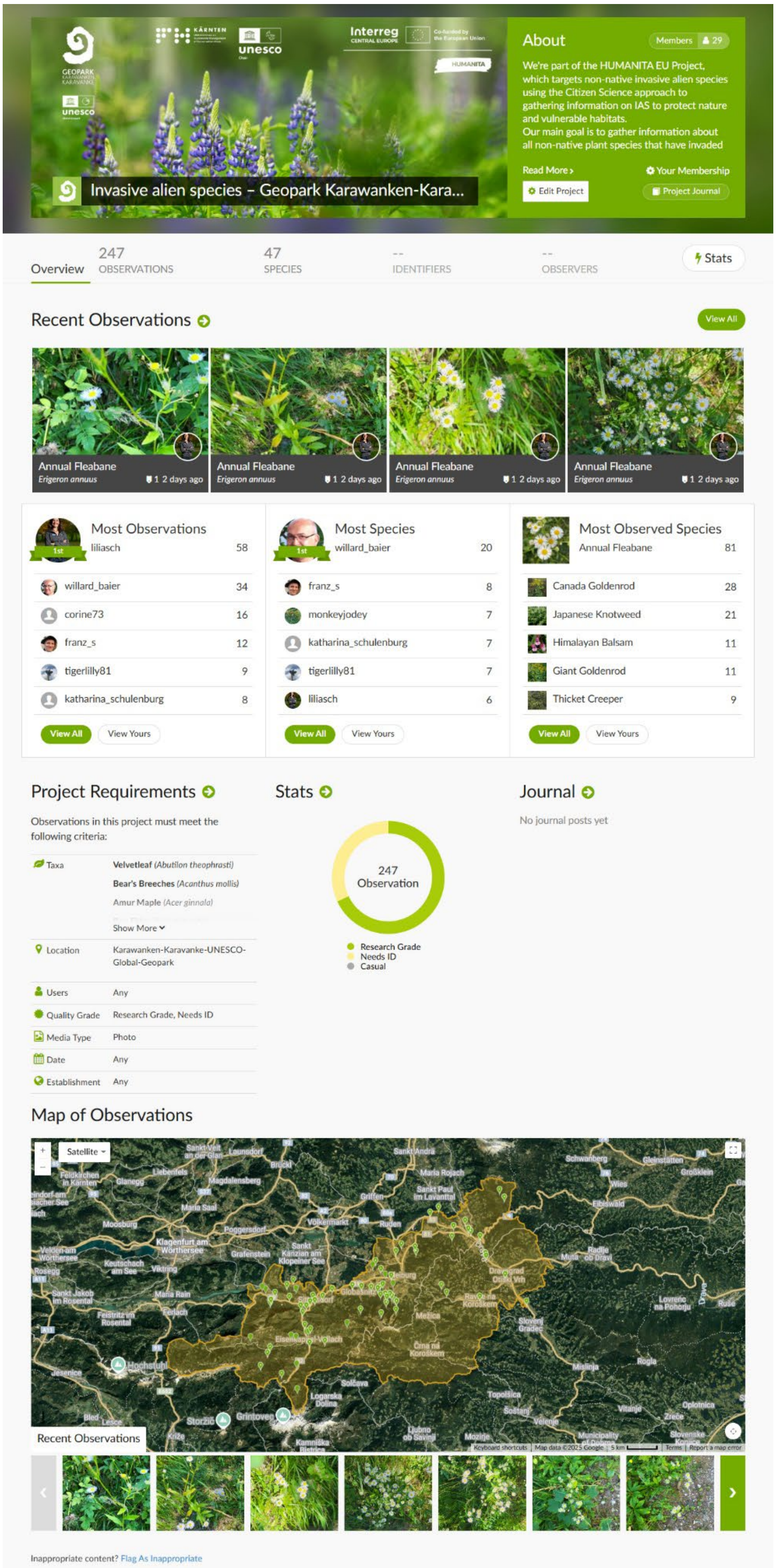
Introductory workshop with alpine associations, mountain hiking guides and tourist organisations to introduce the possibilities to participate in our citizen science project. Summer school activities.

4.4. FUTURE DEVELOPMENTS

In October 2024, the user account (holder of the project) was deleted, and as a result, the project was also deleted. We were accused by the iNaturalist of interference with the quality of the data collection. To clarify our position, we asked for the proof that data collection/observations from our side or any our members accounts did interfere with the quality of the App in any possible way. No proof was presented from the iNaturalist at all; however, they presented all the Geopark team members' personal data information (also information that was not implied in the iNaturalist accounts), which indicated that they are illegally following members and also collecting personal data, which goes against principles and GDPR guidelines. Secondly, they limited the accesses to personal accounts from our Geopark team members. This led to the final decision to delete all our personal accounts. INaturalist lost by deleting our accounts over 20.000 observations. Before final action, the conclusion from the iNaturalist was that we were too active (this action shows that the decision makers are individuals with no big interest of results – the problem can be also that we were collecting IAS, what increased the observations from our side in this aspect, and the iNaturalist is not build for this kind of observations)!

No data were lost because all information was regularly downloaded and updated with every change made to the project (including new observations). The project on iNaturalist was re-established with a new user account that represent the organization (without adding any observations, just for the collecting data purposes), which is the project holder (they deleted the project one more time, when it was recreated (without explanation or reasons), but after second time of recreating it, they stopped interference). This does not affect any activity that was carried out in the past in connection with the promotion of the project, it just opened new windows for better solutions and ideas how to better collect useful information's (parallel project as presented in the following – **direct approach**).

All materials (digital flyers and posters) were adapted with a new QR code and distributed among stakeholders, owners, municipalities and schools. New descriptions were made on platform "Österreich forscht" as well. The materials were prepared by Geopark Karawanken–Karavanke in the past and were adapted by Geopark Karawanken-Karavanke for the future needs (the materials were also presented for Green Academy). The promotion of the iNaturalist project stays on course. The presentation of it were also carried out and promoted in the Geopark Karawanken-Karavanke Schools Network. And was also presented at the Summer School (field work and presentations for students and other participants).


Invasive alien species – Geopark Karawanken-Kara...
About
Members 29
We're part of the HUMANITA EU Project, which targets non-native invasive alien species using the Citizen Science approach to gathering information on IAS to protect nature and vulnerable habitats.
Our main goal is to gather information about all non-native plant species that have invaded
Read More ›
Your Membership
Edit Project
Project Journal
Overview
247 OBSERVATIONS
47 SPECIES
-- IDENTIFIERS
-- OBSERVERS
Stats
Recent Observations
View All
Annual Fleabane Erigeron annuus 1 2 days ago
Annual Fleabane Erigeron annuus 1 2 days ago
Annual Fleabane Erigeron annuus 1 2 days ago
Annual Fleabane Erigeron annuus 1 2 days ago
Most Observations
liliasch 58
willard_baier 34
corine73 16
franz_s 12
tigerlilly81 9
katharina_schulenburg 8
View All
View Yours
Most Species
willard_baier 20
franz_s 8
monkeyjodey 7
katharina_schulenburg 7
tigerlilly81 7
liliasch 6
View All
View Yours
Most Observed Species
Annual Fleabane 81
Canada Goldenrod 28
Japanese Knotweed 21
Himalayan Balsam 11
Giant Goldenrod 11
Thicket Creeper 9
View All
View Yours
Project Requirements
Observations in this project must meet the following criteria:
Taxa: Velvetleaf (Abutilon theophrasti), Bear's Breeches (Acanthus mollis), Amur Maple (Acer ginnala), Show More
Location: Karawanken-Karavanke-UNESCO-Global-Geopark
Users: Any
Quality Grade: Research Grade, Needs ID
Media Type: Photo
Date: Any
Establishment: Any
Stats
247 Observation
Research Grade
Needs ID
Casual
Journal
No journal posts yet
Map of Observations
Satellite
Recent Observations
Inappropriate content? Flag As Inappropriate

4.5. Errors, mistakes and problems/Recommendation and measures:

The example of deleting a user illustrates the issue of potential data loss if data is not downloaded regularly, which must be taken into consideration. It is advisable to regularly transfer and store data on a platform with permanent data storage capabilities. No data observation on the iNaturalist App is permanent, users can delete an observation at any time without warning or notification, and the information is lost. This presents a serious problem when reviewing and collecting the observations. If this were an "unknown" user, we would lose almost 4,000 valued observations (97% of all observations – all observations were adapted to the secondary parallel Citizen Science project – direct approach).

4.5.1. The quality of the collected data needs to be carefully examined and analysed.

In many cases of observations, the **accuracy of locations** is not useful.

A quick analysis reveals that out of the **247 collected observations,** 98 are within 10 meters of the marked location, indicating an accuracy rate of 39.68%. For 68 observations, accuracy was not recorded, which accounts for 27.53%. Additionally, 19 observations have an accuracy range of under 100 meters, representing 7.69%. There are 14 observations with an accuracy between 100 and 500 meters, making up 5.67%, and 48 observations have an accuracy of over 1 kilometre, corresponding to 19.43%. The usefulness of this data is questionable since determining true locations can be challenging.

A secondary indicator of visual inspection of observations is also reflected in the display of observers who, in as many as 51 cases (20.65%), **use the same photo with a different location.** This calls into question the quality and credibility of the observation.

While the iNaturalist offers the option to differentiate between **wild plants** and those found in gardens or parks, many users do not make this distinction. As a result, around 25 observations (10.12%) have been misidentified as wild plants even though the photographs clearly show they are domesticated.

VEGETATION MONITORING: Citizen Science (Invasive Alien Plant Species) – direct approach (Geopark Karawanken-Karavanke)

5.1. STARTING DATE

In November 2024, we launched a parallel project called **Citizen Scientist** (Invasive Alien Plant Species) **- direct approach.** This initiative aims to create a comprehensive database or map of all non-native plant species found in the Geopark Karawanken-Karavanke area. We plan to achieve this with the assistance of the local community, engaging individuals through the Citizen Scientist approach. Our goal is to cover as much area as possible to gather crucial information on the presence of non-native species in the Geopark Karawanken–Karavanke.

The strategy focuses on connecting with individuals from specific interest groups related to outdoor activities like hiking, photography, or nature enthusiasts. The main method is direct, personal contact tailored to each person's chosen interest, ensuring meaningful engagement with those already interested in the topic.

5.2. METHODOLOGY DESCRIPTION

The process consists of three main phases:

- gathering data and clues from individuals through brief, productive interviews,
- identifying non-native plant species and confirming locations (field work),
- and entering the collected data into a database (Geopark Karawanken-Karavanke).

We conducted several interviews with dedicated members of the local community (nature enthusiasts, wildlife photographers, mountain guides, ...) to gain clues and information on the location of the Invasive Alien Plant Species in the Geopark.

5.2.1. PROJECT GOALS

Building Scientific Capacity with the help of the Citizen Scientist community:

- Encourage participants to take part in data collection, engage in environmental assessments, and develop critical thinking skills through basic training and collaboration with researchers.

Support Evidence-Based Decision Making:

- Create accurate, community-driven environmental database to guide policies, conservation efforts, and resource management decisions.

Cooperation:

- Enhance teamwork among local communities, scientists/experts, NGOs, and government agencies by setting shared monitoring goals and creating research and monitoring initiatives together.

Among everything, raising awareness and involving selected volunteers has also sparked interest among secondary participants. These participants, through the main information channel, offer clues about the locations and confirmations of non-native species in the environment, sharing valuable insights through active volunteers or direct contacts.

Management and Control: Developing an action plan to control and contain invasive species to protect native ecosystems.

5.3. RESULTS AND OBSERVATIONS

So far, more than **22,000 locations** of non-native plant species in the Geopark Karawanken-Karavanke have been recorded in the database, based on collected clues and confirmed findings (most of them are Invasive Alien Species). Over 60 non-native plant species have been identified, and there are still over 5,000 clues awaiting verification.

No physical "samples" were needed throughout the process, except for individual photo materials used to identify species. Once the species and location were confirmed, the photos were not archived. In this context, "samples" refer to digital databases used for further analysis and creating the IAS map in the future.

Monitoring data acquisition is important and demands more time and energy compared to using an App. This highlights both the positive and negative aspects of the approach. While the initial phase of collecting data, information, or clues is faster and more extensive than any app, the second and third phases are more time-consuming but yield better confirmed results – easily eliminating inaccurate information with more verified location accuracy (even additional discoveries of the IAS on the way). The key factor is having a well-organized logistical design for verification through zoning the area of interest effectively.

Invasive Alien Species – Karawanken-Karavanke UNESCO Global Geopark

HUMANITA Project - CITIZEN SCIENTIST

Japanese Knotweed *(Reynoutria japonica)* and its relatives: Rhizomatous Knotweeds *(Genus Reynoutria)*, Giant Knotweed *(Reynoutria sachalinensis)*, Bohemian Knotweed *(Reynoutria × bohemica)*

	ID	Infected area	Number of plants	Coordinates	Year of observation	WILD	Observer	ACTIONS	Proof	Note
1	Japanese Knotweed *(Reynoutria japonica)*		1	46.53079, 14.90038	2024	YES	Urosh Grabner	NO	In person!	**Leše**
2	Japanese Knotweed *(Reynoutria japonica)*		2	46.53091, 14.90067	2024	YES	Urosh Grabner	NO	In person!	**Leše**
3	Japanese Knotweed *(Reynoutria japonica)*		1	46.53209, 14.90277	2024	YES	Urosh Grabner	NO	In person!	**Leše**
4	Japanese Knotweed *(Reynoutria japonica)*	0,051 ha + (155 m +)	> 5	46.53916, 14.91424	2024	YES	Urosh Grabner	NO	In person!	**Leše!** Road repairs...
5	Japanese Knotweed *(Reynoutria japonica)*	0,008 ha + (51 m +)	> 15	46.53806, 14.81933	2023/2024	YES	Urosh Grabner	NO	In person!	
6	Japanese Knotweed *(Reynoutria japonica)*		1	46.53856, 14.81899	2023/2024	YES	Urosh Grabner	NO	Photo!	
7	Japanese Knotweed *(Reynoutria japonica)*	0,014 ha + (50 m +)	Large bush	46.54088, 14.81747	2024	YES	Urosh Grabner (local info)	NO	In person!	The plant is located at the edge of a stream, and it may have spread both upstream and downstream. A survey of the are
8	Japanese Knotweed *(Reynoutria japonica)*	0,009 ha + (39 m +)	Large bushes	46.54233, 14.818	2024	YES	Urosh Grabner	NO	In person!	The plant is located at the edge of a stream, and it may have spread both upstream and downstream. A survey of the are
9	Japanese Knotweed *(Reynoutria japonica)*		> 5	46.55907, 14.75226	2024	YES	Urosh Grabner	NO	Photo!	**Pirkdorfer See**
10	Japanese Knotweed *(Reynoutria japonica)*		> 5	46.55903, 14.75242	2024	YES	Urosh Grabner	NO	Photo!	**Pirkdorfer See**
11	Japanese Knotweed *(Reynoutria japonica)*	0,005 ha + (34 m +)	> 25	46.56633, 14.80582	2024	YES	Urosh Grabner	NO	Photo!	**In the settlement**
12	Japanese Knotweed *(Reynoutria japonica)*	0,110 ha + (166 m +)	> 25	46.55684, 14.76708	2024	YES	Urosh Grabner	NO	Photo!	In the woods near the road! Dumping place...
13	Japanese Knotweed *(Reynoutria japonica)*	0,024 ha + (80 m +)	> 25	46.60284, 14.7969	2023.2024	YES	Urosh Grabner (local info)	NO	Photo!	By the stream...
14	Japanese Knotweed *(Reynoutria japonica)*	0,151 ha + (152 m +)	> 100	46.59168, 14.80058	2024	YES	Urosh Grabner (local info)	NO	Photo!	Abandoned plot...
15	Japanese Knotweed *(Reynoutria japonica)*	0,034 ha + (74 m +)	> 50	46.57182, 14.80277	2024	YES	Urosh Grabner (local info)	NO	Photo!	
16	Japanese Knotweed *(Reynoutria japonica)*		> 20	46.55217, 14.80875	2024	YES	Urosh Grabner	NO	Photo!	
17	Japanese Knotweed *(Reynoutria japonica)*		> 20	46.60297, 14.79686	2024	YES	Urosh Grabner	NO	Photo!	
18	Japanese Knotweed *(Reynoutria japonica)*	0,901 ha + (449 m +)	> 25	46.60011, 14.80284	2024	YES	Urosh Grabner	NO	Photo!	In the woods...
19	Japanese Knotweed *(Reynoutria japonica)*		> 50	46.59185, 14.80054	2024	YES	Urosh Grabner	NO	Photo!	
20	Japanese Knotweed *(Reynoutria japonica)*		> 50	46.57178, 14.8028	4/3/2024	YES	Urosh Grabner	NO	Photo!	
21	Japanese Knotweed *(Reynoutria japonica)*	0,009 ha + (51 m +)	> 15	46.55179, 14.80921	2024	YES	Urosh Grabner	NO	Photo!	

Cutleaf coneflower – Goldquelle | Daffodils | Fountain Grass | Foxglove-tree | Garden Tulip | Giant Hogweed | Himalayan Balsam | Horse-Chestnut | Horseweed | Japanese Knotweed | Japanese Spirea

Figure 28 Sample of data collection – Excel

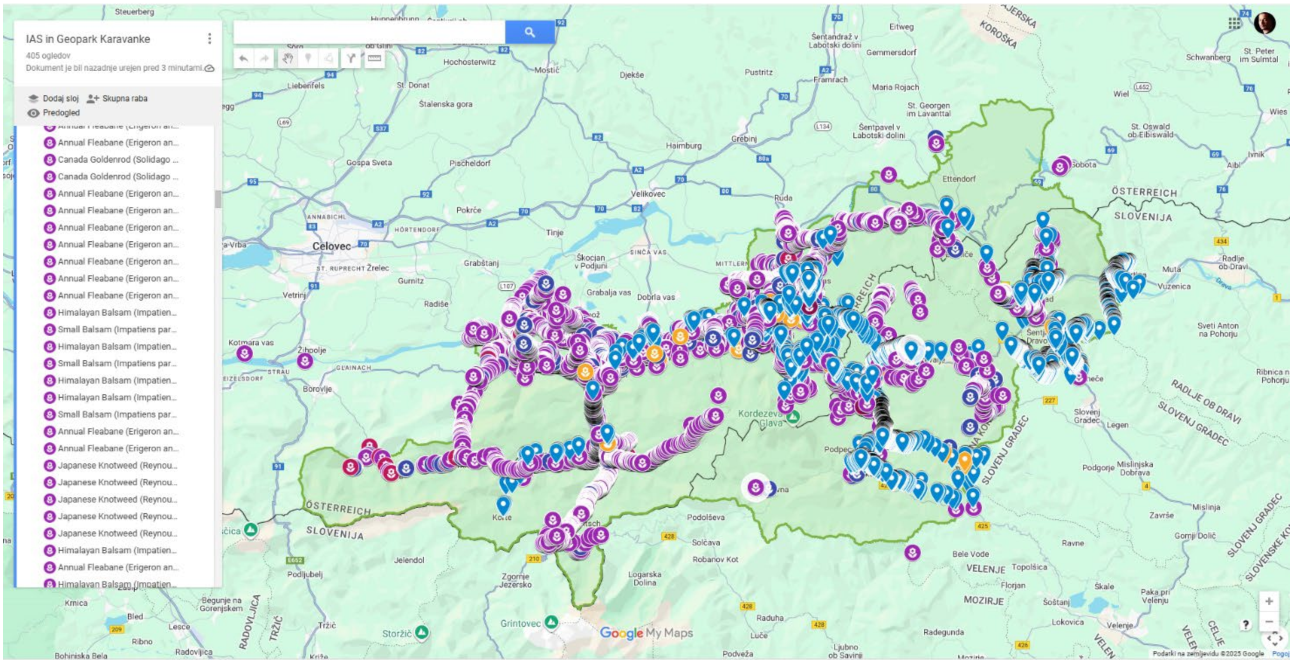


Figure 29 Sample map of IAS map Karawanken-Karavanke UNESCO Global Geopark

WILDLIFE MONITORING/OBSERVATIONS (Geopark)

6.1. STARTING DATE

Monitoring (observation) started in 2025 (summer season). Selection of camera positions was based on the implementation plan. where the animals are present and effected due to visitor precense during the peak of the tourist season. The observations will also continue in the future.

6.2. METHODOLOGY DESCRIPTION

The aim of monitoring is the observation of the wildlife near the trails to determine the presence and behaviour of the wildlife when visitors are present and when visitors are absent. We will not count the animals (the pattern and timeline are too short for useful results). We will not monitor visitors with wildlife cameras

We want to see the interaction (human-wildlife relationship), impact, behaviour and presence of wild animals in hiking and biking trails and how this influences wildlife in our pilot sites.

We are using 20 Wildlife cameras (EVOLVEO StrongVision PRO 4G).

The implementation plan for the location of the Wildlife cameras cannot be part of the report. The locations cannot be publicly known to avoid stealing and damaging the equipment or using the observations for harming wildlife.

Wildlife cameras are placed in specific locations to gather data on human-wildlife interaction, behaviour, impact, and presence of wild animals. This data will be utilized for conservation efforts, such as suggesting adjustments to hiking and biking trails to protect habitats or proposing designated quiet zones during mating season, etc.

6.3. RESULTS AND OBSERVATIONS

- 20 locations were determinate on Petzen/Peca. All 20 locations caught Wildlife through the observation method by changing angles and adjusting positions within a narrower range of hiking trails and increased visitor activities/presence in nature.
- Some positions with high frequency of visitors did not catch any wildlife activity in the summer season and shows wildlife activities only by ending of the summer season.
- First evaluation, results and findings will be carried out by the end of 2025. So far various species could be identified. Some of the caught species are vulnerable. Their presence emphasizes the ned to increase preservation efforts.
- The initial collective survey confirms the presence of at least 10 mammal species and several bird species.
- Wild animal activities in the observation area are mostly limited to times when there is no human presence (nighttime, early morning, late evening). At day time wildlife could be detected during bad weather conditions, which is probably related to the absence of people on such occasions.

- With quick tests we did not detect problems with equipment. Wildlife cameras work as expected. The only problem with what we do not have influence on is that we need the presence of the animals for catching them. If they are not present it might be the result of human pressures on the area.
- One camera was damaged by a visitor, despite the wildlife observation area being away from human infrastructure. Hiking trails go beneath or above the observation areas, not directly through them.

6.4. FUTURE DEVELOPMENTS

Wildlife cameras are in positions on Petzen/Peca for what we have permits.

Recommendations:

- Buy quality wildlife cameras (quality video and photos and better choice of settings), with lithium batteries (longer lifetime of energy).
- Do not reveal the locations of the observations to avoid the presence of humans, potentially stealing or damaging the equipment. We also strongly recommend installing two or three cameras in the same spot (covering the angles from one to another camera – more area to cover and video collection of potential stealing one of the wildlife cameras).
- We also recommend using auto download to the distance (data transfer with sim card, even so, that we didn’t use these options on locations).
- Use settings video/photo for better result (A one-second delay (standard) in the video/photo setting can result in a captured movement being captured in only one of the options. This way, at least one method of capturing can be successful in the result).
- Avoid (if possible) pointing cameras directly to the east or west (direct sun), unless the animals' activities in the wild are in shady locations or are limited to nocturnal activities.
- It is also necessary to know well the patterns and habits of animals in nature and the potential locations of observations for a better result of observations (species, mating seasons, migrations, etc).

Figure 30 Samples of wildlife catch with Wildlife cameras:

EROSION MONITORING (Geopark Karawanken-Karavanke + Uni Parma)

7.1. STARTING DATE

The first monitoring with the University of Parma take place in the beginning of May 2024 and the second during 4th HUMANITA Partner Meeting on 10th of September 2024.

7.2. METHODOLOGY DESCRIPTION

The main objective of this activity is to evaluate the effect of anthropic activities in terms of soil erosion and trail conditions, by exploiting different monitoring approaches and techniques.
We used (in collaboration with the University of Parma) ground and remote techniques to monitor soil erosion and sedimentation rates with centimetre accuracy at a selected location, specifically a bike trail. We envisage the comparison process in three comparative iterations throughout the project. The methods involve analysing 3D models and comparing point clouds to quantify erosion in a dedicated period.

The selected approaches were introduced to survey trail segments of varying lengths, which could also include narrow paths in wooded areas. For this application, we opted to employ two different methodologies both based on photogrammetric sensors: the first one involves an aerial-based approach by using an UAV compact enough to fly in forested areas, while the second one relates to spherical imaging techniques by exploiting a backpack-mounted 360 camera. The two-technique approach was also selected with the secondary objective of verifying their efficiency and adaptability to specific scenarios, to provide more comprehensive guidelines on trail erosion monitoring approaches.

7.3. RESULTS AND OBSERVATIONS

The UAV-based survey was employed on two sections of the bike trail, flying manually under the wood canopy and following the path. The survey was also extended outside the selected trail, flying at higher altitudes in an open area to collect more accurate GPS data; it should be noted that no evaluation of soil erosion phenomena is planned for this specific area.

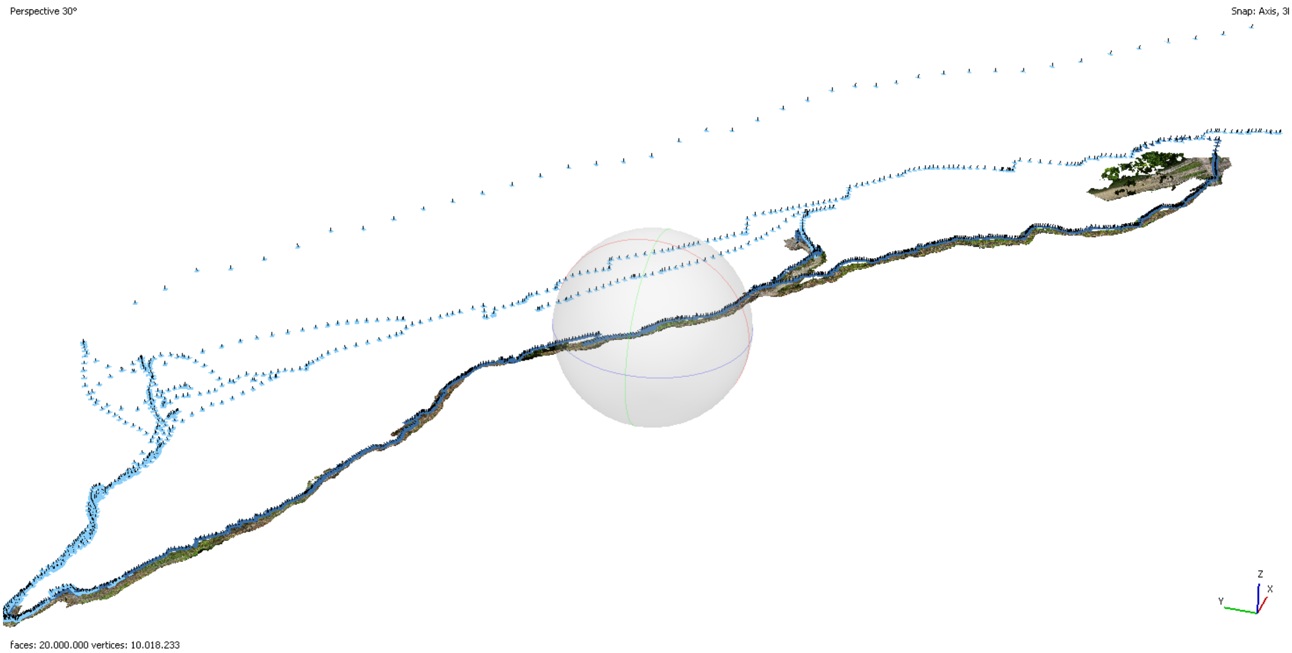


Figure 31 Results from erosion monitoring whole transect.

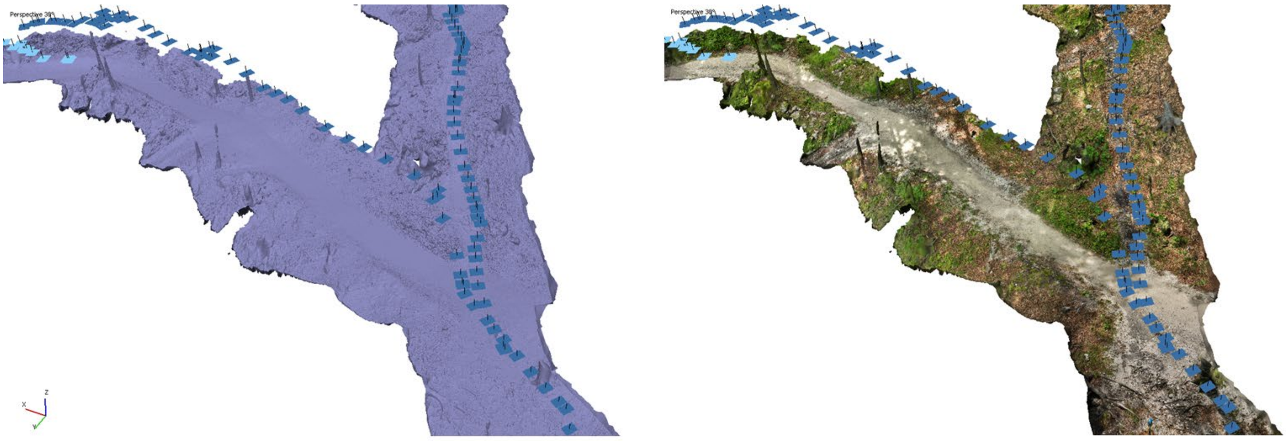


Figure 32: Result from erosion monitoring DSM and Orthofoto

The methodology proved to be a viable solution for trail survey activities, providing accurate Digital Surface Models of the monitored area. However, some limitations emerged during the survey execution:

- The possibility to create and store flight plans in advance is one of the main advantages of the employment of UAV-based techniques, since the survey can be performed automatically with optimized parameters. However, when flying under the wood canopy, the high number of obstacles requires manual execution of the survey by the operator, thus eliminating the convenient option to pre-plan the flight path.
- Due to the very low flight altitude (2-3 meters), the drone must operate at extremely low speeds (approximately 0.3 m/s) to ensure adequate photo overlap, which is fundamental to generate the final DSM. As a results, the sampling process could become quite time-consuming for long trail sections.

The introduction of a backpack-mounted spherical imaging sensor was specifically chosen to address these issues, enabling semi-automated surveys in densely vegetated areas where aerial sensors would be less effective. Nonetheless, it should be noted that the selected acquisition method - capturing images via 2-second time-lapse — requires the operator to move at a relatively slow pace, which still makes the process somewhat time-consuming. Despite this, compared to UAV surveys in similar environments, spherical imaging offers advantages in terms of efficient battery management and ease of use, making it a valuable addition to the toolkit for trail survey activities. Data collected with the 360 panoramic cameras are currently under elaboration.

7.4. FUTURE DEVELOPMENTS

The main objectives for the forthcoming period involves the completion of the elaboration process for all available datasets, to provide a first comparison between subsequent surveys. Moreover, with the introduction of visitor counters in the area of interest, and by repeating the on-site sampling activities here described, it will be possible to analyse different information to investigate the presence of cause-effect correlations with human activities and their impact on trails condition.