Geo-Dolomities, exploration of alpine huts, peaks and trails.

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Abstract: This project presents a large-scale analyses on the Dolomities; investigating, from a geospatial point of view, their morphology and the most important point of interest such as the alpine huts and the major peaks. We will perform a network analyses on all the trails that allow to visit those mountains, generating insightful description and details on the difficulties and possible routes to follow connecting them to the street network. Lastly we will perform a spatial analyses to understand if there is some correlation in the prices of the alpine huts according to the area in which they are located. This report will briefly cover the most important steps, however in the notebooks that are linked is possible to see in detailed the actual implementation and minor features as well as with interactive maps.

Keywords: GeoSpatial; Osmnx; OpenStreetMap; Dolomities; Python; R; SpatialRegression.

1 Introduction

In this report we will discuss how we performed a geo-spatial analyses on the Dolomities, focusing particularly to their major points of interests such as alpine huts and high peaks. We also perform a network analyses including the graph of all the trails and streets present in the region of Trentino-Alto Adige that allow to reach those mountains. These analyses will allow us to discover the shortest trails to the alpine huts with the related details such as the expected duration, the difference in height and the length.

The project is divided in 4 sections, each of them is specific to analyse a particular aspect of the topic:

1. Dolomities area exploration.
2. Alpine Huts and Peaks exploration.
3. Trentino Trails-Streets Graph Analyses.
4. Alpine Huts Spatial Correlation Prices.

In the first section we will explore the entire area of the Dolomities, pointing out their location with respect to the Italian regions and its municipalities, calculating some basics statistics; we will study their morphology visualizing and investigating the lakes and the glaciers that are present; The last point of this first section concerns a general exploration of the alpine huts retrieved from the official website of CAI and geo-coded through Nominatim service.

In the second section we will explore all the alpine huts, not only the ones from CAI website, and the peaks. We will retrieve the data from the OverPass API that allow to extract information from OpenStreetMap graph, focusing on the data geo-located in the North-east area of Italy. We will perform some analyses pointing out the major characteristics as the elevation, Dolomities group and province of belonging, the distance between the alpine huts and peaks greater than 3000m and highlighting the cost of the alpine huts (only for those from CAI).

In the third section we will focus on the trails; first starting from the ones maintained by SAT and then using all the possible trails extracted with OpenStreetMap in the interested area. Doing this we will be able to generate real trails to reach each hut in the Dolomities. Moreover while doing this operation we will also add the elevation to each node in the graph allowing us to predict a travel time for complete the trails, this time is directly dependent on the difference in height of each piece of the trail. We will explore better the relation between peaks and huts exploring where it actually exists a path that bind them. Then we connect the trails and the street graph calculating the optimal trail for each hut from the street taking in count the actual difference in height between the starting point-alpine huts and the generating insightful details such as the expected walking time and level of difficulty of trail.

In the fourth section we will perform a simple spatial regression in order to understand if there is some kind of correlation in the prices of the hut's half board; we will also explore other possible explanatory variables such as the elevation of the hut and the capacity of the sleeping accommodation.

Lastly we will point out all the Data Licences and the sources of the data used.

2 Dolomities area exploration

The first section is related to a general overview over the geoarea of the Dolomities. we've been able to retrieve the boundaries of all the 9 groups of Dolomities from the official website of the Dolomities. After a first visual exploration we have calculated some basics statistics such as the extension in km^2; Then we have integrated these data with the administrative boundaries of the Italian regions, provinces and municipalities so to have a better insight on the location of the mountains related to the Italian boundaries and investigating which are the regions and municipalities that most are close and in touch with the mountains.

Dolomities area over italian regions

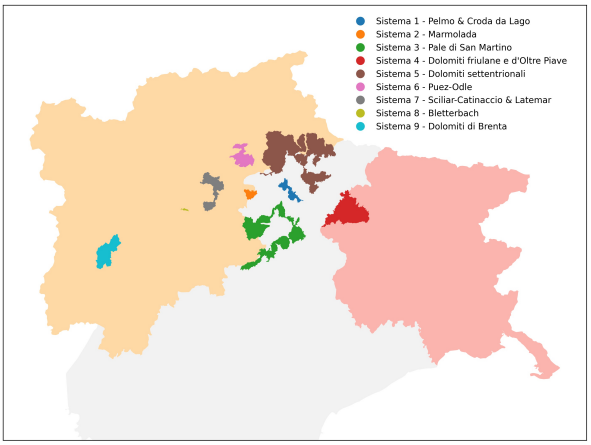

Figure 1: Dolomities region

Following this first step we've started exploring the the morphology of the Dolomities, focusing on the lakes and the glaciers that are present in the area. We've retrieved the data regarding the water basins using the Catalogue Service Web of the *Italian Geoportale Nazionale* and the data regarding the glaciers from the *Comitato Glaciologico Italiano*. As before we've computed the basic statistics and visualized them.

Glaciers and Lakes in the Dolomities area

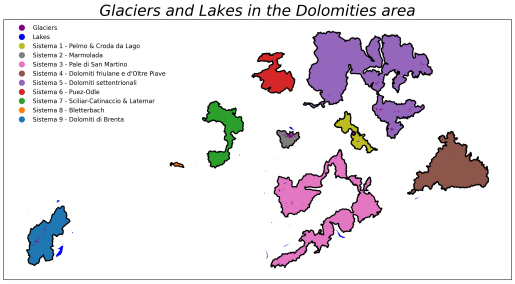

Figure 2: Dolomities Glaciers and lakes

In addition to this we also explored the tragedy of the Marmolada Glacier in July 2022, visualizing the path of the "*Via Ferrata Normale*"; the position of the collapsed glacier and the possible trajectory that has swept away the trail.

This first section is concluded with a brief exploration of the alpine huts that are managed by CAI institution. We found the details of the huts on the official website of CAI. These data contains many details of the huts such as the opening periods, owner, capacity, elevation and many others but their geo-location is missing. In order to obtain this information we used the Nominatin Geocode for identifying the exact location given the hut's name. Then we manually extracted the prices of these huts creating a simple file .csv that we used later on when performing the spatial correlation of the half boards prices.

3 Alpine Huts and Peaks

In this section we have explored deeper all the alpine huts and the peaks that are nearby the area of the Dolomities. Differently from before we used the data from OpenStreetMap through the Turbo OverPass API, saving the data into .geojson using the following queries:

```
[out:json][timeout:25];
// [Veneto, Trentino, Friuli-Venezia Giulia]
{{geocodeArea:Veneto}}->.searchArea;
(
```

```
  node["tourism"="alpine_hut"](area.searchArea);
  way["tourism"="alpine_hut"](area.searchArea);
  // query part for:   peak
  // node["natural"="peak"](area.searchArea);
);
```

Regarding the alpine huts we highlighted their position with respect to the group of Dolomities/provivinces to which they belong and their elevation; we have performed the same operation with peaks. The information is summed up in the following group of plots, regarding the alpine huts:

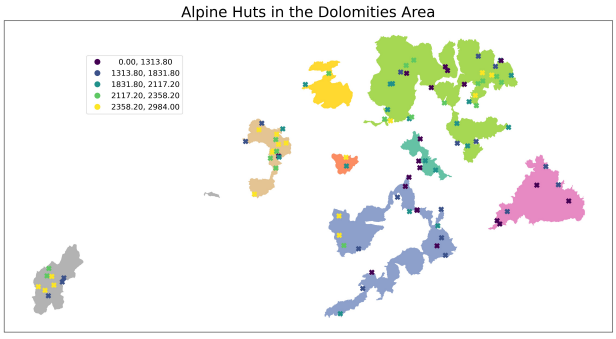

Figure 3: Huts according to the elevation

We can notice that the alpine huts that are the highest are concentrated in *Dolomiti settentrionali* (36 in 536 km^2) which is also the largest group, then we have *Pale di San Martino* (19 in 317 km^2), *Scillar* (18 in 93 km^2) and *Brenta* (9 in 111 km^2). While regarding the highest peaks for simplicity here we report only the peaks that are higher than 3000m:

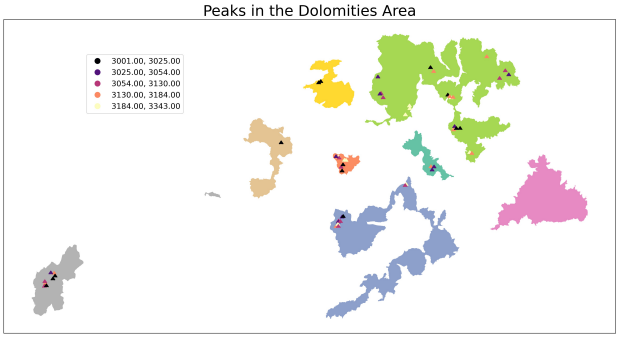

Figure 4: Peaks according to the elevation

The distribution for the peaks is quiet similar as the huts, apart from *Marmolada* which contains 8 high peaks and the group of *Scillar* which contains only 1 very high peak.

Lastly in this section we have naively computed the distance between the highest peaks and the huts, trying to understand which are the peaks reachable from neighbour huts and their absolute distance and difference in height.

4 Trentino Trails-Street Graph Analyses

This section is dedicated to the exploration of the network of trails and streets in Trentino-Alto Adige. Before using the whole network from OpenStreetMap we have tried to use the data from SAT (Società Alpinisti Trentini) for having an overview of the trails. To generate this insight we performed some visualization and analyses to understand which alpine huts were reachable from the SAT trails and which were not; After this first approach we started using OSMNX for retrieving a real graph-based data for representing the trails that were present in the Dolomities. Due to the amount of data we extracted the *walking* network of the only buffered geometry of the mountains obtaining the follow:

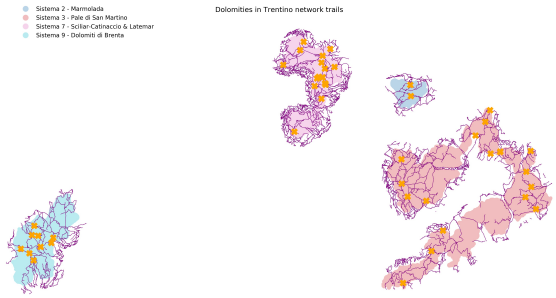

Figure 5: Trentino Trails

Once obtained this trails graph we mapped the alpine huts and peaks respectively on the graph, searching for the nearest already existing nodes present and discarding the peaks that were too far from the nearest node (distance grater than 1km).

Then thanks to the Open-Elevation's API we've been able to add for each node its altitude; with

this information we then add the edge speeds on each trails allowing the computation of the travel time. More than that we've been able to compute the shortest path not on the raw length but including a penalty that is directly related to the altitude difference between each segment of the trail; this penalty is based of the absolute grade of the edge and the direction (uphill or downhill).

To do so we first modified the "highway" types of each edge according to the level of grade (how much difference in heights between two nodes), we fix a maximum speed and then we've created a custom "highway speed" according to the slope of each segment that compose a trails.

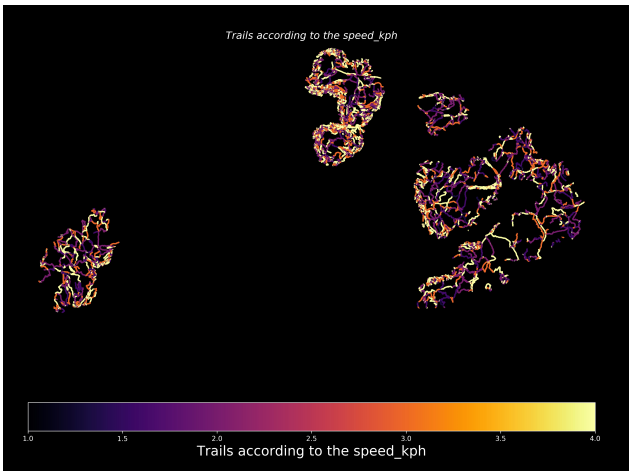

Figure 6: Trails according to time travel

Before connecting the streets network we decided to repeat the operation of binding the huts with the peaks but this times using the real trails and computing the statistics of the path such as duration, difference in height and length.

The last part of this section is related to the streets network of Trentino-Alto Adige and the point of intersection between trails and streets. Since we maintained the two graph separated we had first to find the connecting points between the two, namely the points that allow to move from one graph to another.

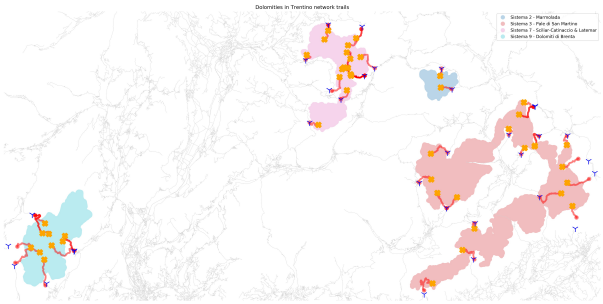

Figure 7: Streets-Trails access point

Now that we have all these elements we've been able to connect the two major city, Trento and Bolzano, to each huts in the Dolomities; basically once chosen the starting point and the alpine hut we can obtain the shortest trail and the necessary information such as the estimated time, the grade, the total elevation (ascend or descent), the length of the trail and also the streets route from the selected city to the starting point.

The following part is also interactive using the notebook is possible to generate the route for the desired huts:

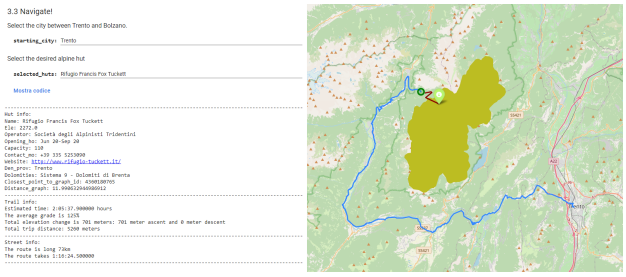

Figure 8: Streets-Trails access point

5 Alpine Huts spatial correlation prices

This section is related to the alpine huts prices, we tried to investigate the distribution of prices among the different alpine huts in Dolomities; We collected manually the data from the SAT website where we found a detailed list of prices for each of the hut handled by them. We point out that due to the limitation of the data (limited to 30 observation) we do not reach a valid statistical significance even if the obtained strictly significance values.

In order to compute this operation we need first to define the neighbours of each data points, we've done this following two different approaches: using the k-nearest neighbours criterion which implies that two spatial units are considered as neighbours if their distance is equal, or less than equal, to the minimum possible distance that can be found amongst all the observations and the critical cut-off neighbourhood criterion which implies that two spatial units are considered as neighbours if their distance is equal, or less than equal, to a certain fixed distance which represents a critical cut-off. We tried with different K and with different critical cut-off so to have a better overview of what is happening.

Once we have defined the neighbours then we've built the spatial weight matrices and we analyzed the huts relative to the variable (Half board - no partner). To do this operation we used the Moran I test under normal assumption, under randomisation and with Monte-Carlo simulation. The results between the three approaches are quit coherent and points out that when using a very close range to define the neighbour than there is spatial correlation that affects the prices of the huts while if we enlarge the range of neighbours then it seems that there is no correlation. Here we present only the relevant results, see the Rmarkdown to see all of them.

Table 1 Moran tests under randomisation

distance	P.value	Moran I stat
K=1	0.005279	0.5075
K=5	0.00246	0.2129
cut_off=min	0.0019	0.2456
cut_off=min+50%	0.00063	0.1672

Since we have also others indicator of the prices as well as other possible explanatory variables such as the capacity of the hut and the elevation we performed a simple linear regression over them to see if we find some significance and as expected we can notice that the elevation is a very significant variable for explaining the prices while the capacity is not.

Table 2 Coefficients of LM

variable	estimate	std	P.value	
Intercept	1.455e+02	4.811e+01	0.00669	**
elevation	3.370e-03	3.584e-04	8.82e-09	***
capacity	1.308e-03	5.004e-03	0.79646	

We can state that the spatial correlation is present especially if using a close range for defining the neighbours and the elevation is also a great factor for defining the prices of the alpine huts. We can further hypothesize that the closest huts tend to be similar in elevation and this can justify also the spatial correlation. However we remind that this last analyses was performed on a very little amount of data.

6 Conclusion

In this report we discussed and presented an analyses over the Dolomities and their point of interests such as alpine huts, peaks, natural hydro basins and the network of trails and streets that allow to explore them, obtaining some useful information about the whole area.

We also performed a brief analyses on the possible presence of spatial correlation between huts half board prices, pointing out that could be possible also due to the elevation of them.

7 Data Licences

links and licenses:

1. area dolomiti, license not specified
2. italian boundaries, (CC By 3.0 IT)
3. Laghi e altri specchi d'acqua interni, (CCO 1.0)
4. Glaciers, license not specified but thanks to Salvatore M.C., Zanoner T., Baroni C., Carton A., Banchieri F.A., Viani C., Giardino M., Perotti L. (2015).
5. Trentino Ortophoto, (CC BY 3.0 IT).
6. CAI alpine huts, lincense not specified
7. OSM Alpine huts (CC BY-SA 3.0)
8. OSM peaks (CC BY-SA 3.0)
9. SAT trails (ODbL
10. OSM Trails (CC BY-SA 3.0)
11. OSM Streets (CC BY-SA 3.0)