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Research Article

Open Spatial Data from Satellite for Mapping and Monitoring the Refugee Camps: Testing Sentinel-2 on Lipa Case Study (Bosnia)

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ABSTRACT

The impasse caused by the COVID-19 pandemics has opened a call for updated data to highlight and avoid possible critical situations in one of the hottest issues for the external politics of the EU, such as the refugee camps. Within this framework, the new geospatial technologies and platforms such as public satellites might represent an opportunity for monitoring and assessing refugee camp dynamics. The general aim of the present work is to map, to assess and to monitor spatial pattern and population of the refugee camp of Lipa in Bosnia. By this case study is shown the possible application of the recent open and updated satellite data in terms of spatial analysis by adopting a simple algorithmic workflow able of generating valuable data for those who work in the field. Also, analyse the migrant's situation in Lipa with a frequency of 10 days processing open-source Sentinel-2 data.

Keywords: Refugee camps; Monitoring; Algorithmic

INTRODUCTION

During the last years, refugees became one of the hottest issues regarding the external and internal politics of the EU states. From a spatial perspective, the migrant's phenomenon has brought the rise of many refugee camps, some are built by the national authorities to control and monitor the fluxes, and other are spontaneous, developed by the migrants on its routes.

As a result, the European Union has decided for 2021 to increase the budget of Frontex. The agency monitors and handles these thematic in the count of the EU ministry of foreign and has a solid presence of their officials on the field.

In 2020, the annual budget for Frontex, the body responsible for protecting the external borders of the European Union, increased to 460 million Euros, compared with 333 million Euros in 2019. Annual report of frontex made by Statista.

Therefore, NGOs and the United Nations, which have been working on the ground over the years, have repeatedly resorted to spatial data processing to understand these fields' physical and organisational problems [1,2]. For example, calculating the growth over time and the population is mandatory.

This view from the top could also be used to compare the facilities' data on the ground and those given by the authorities on the field, revealing if the UNCHR guidelines are observed. The official UNCHR emergency handbook. The latter represents the UN's rules to give the refugees a good living standard determining the structures that should be present in the camp. The use of GIS to give feedback on the refugee camp situation represents a mandatory issue in the field of humanitarian assistance and an aim of this paper.

The recent mobility restriction due to the COVID-19 pandemic has highlighted the grown of problematics concerning refugee's situation and the latter could be resumed in:

- A lack of facilities in the bordering countries [3].
- Call for updated data on the field [4].

In this paper, we will present the case study of the refugee camp in Lipa, Bosnia, situated near the EU border of Croatia. We decide to focus on this field because, in recent times, the camp has changed its forms due to a problem concerning a lack of facilities [5]. The camp was partially destroyed by a fire in January 2021, leaving the refugees in the cold of the Serbian winter. This situation had a planetary media impact, bringing attention back to the situation of migrants and highlighting the slow response by the international authorities. Lipa is an

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example of the need to monitor camp situations near the European border [6]. Many newspapers around the globe have focused the situation in Lipa and the problematic concerning the migrants in that period.

These reasons have brought us to focus our case of study on the example of Lipa, trying to see if there was a way to highlight and monitor these critical situations using a vision from above. Furthermore, the recent development of many pythonic libraries able to elaborate spatial and satellites data gives us the instrument for building algorithmic automation suitable to our purpose. We refer to libraries such as GDAL, Rasterio and Geopandas, and their powerful elaboration of "big" satellite datasets.

Hence, our research question is: could the satellite data be elaborated to highlights and report what has happened in Lipa during this year?

This challenge is what we are going to face in this paper, but also looking for the broader implication to this new vision over the refugee dimension. We will do that by focusing on one of the most valuable characteristics of GIS data, its "dynamism" [7] because the data collected about the camp could be compared and overlapped, highlighting the risk and allowing the authority to act accordingly.

Study area

The study area is located in Lipa, Bosnia, near the border of Croatia. It represents the refugee camp of Lipa, one of the largest situated near the European border. The camp host primarily refugees from the middle east nations, such as Syria and economic refugees from north Africa. It is run and monitored by the Serbian authorities in combination with Frontex agents from the EU. (Figure 1 and 2).

Figure 1: The refugee camp of Lipa in summer 2021.

Figure 2: Position of Lipa and satellite image from October 2020.

Data

This study used Sentinel-2 scenes (date of acquisition between April 2020 and July 2021). Sentinel-2 is a European multi-spectral imaging mission. It is composed of two satellites flying in the same orbit but phased at 180°; it is designed to give a high revisit frequency of 5 days at the Equator. Their instruments can sample images with 13 spectral bands: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution (ESA, 2021). For our purpose, we used the 10 m data to create our dataset. Precisely we used the 10 m resolution near-infrared band (central wavelength of 842 nm) combined with the red band (central wavelength of 655 nm) to compose an NDVI index, which is the starting point of the algorithmic elaboration of the data. Later we compose a flow of geoprocessing capable of highlighting the grown of Lipa's field with a frequency of 10 days.

Additionally, the Google Earth imagery and QGIS software were used to visualise and analyse the results. All image processing and analyses were carried out in Spyder IDE and Python 3.8. The algorithm uses the library of GDAL, Rasterio, Geopandas and Folium for the data processing and representation.

For the elaboration and the comparison of the data obtained by the algorithm, we refer to the demographic data of Lipa taken from the UNICEF website. This dataset is updated every month and express the population of the camp. Also, the population data are compared with the independent data from the Borgen Project, a nonprofit organisation, to validate it. Many newspapers around the globe have focused the situation in Lipa and the problematic concerning the migrants in that period.

METHODOLOGY

"Cascata" algorithm, calculating the area length of the field

To reply to our central question, we decide to create an algorithmic automatisation capable of calculating the area of the refugee camp of Lipa in a certain period. It is composed of a series of geoprocessing patterns, and the output is a single geojson vector file contained all the metadata, the area calculation and a "DateTime" column linked to the sensing data of the input satellite dataset.

As input, the algorithm needs only the unzipped path of the 10m images of Sentinel-2 witch is possible to download from the Copernicus hub. Also, the path should be linked to the XML contained in the Sentinel folder to extract the metadata (this is the preliminary step).

The composition of the algorithms concerns eight steps and starts from the calculation of an NDVI. We decide to start from an NDVI processing of the satellite data according to their demonstrated capacity to analyse and monitoring urban and artificial areas [8-10]. As in the cited studies the NDVI was used in many cases to highlights and circumscribe artificial surfaces. An example is the use of this index in mapping impervious surfaces. As Lipa camp is represented by artificial surfaces surrounded by vegetation, the application of this index might give high performance for mapping the camp's perimeter. What are we going to do, starting from this point, is follow the methodology applied in the construction of the algorithm and later discuss the results. (Figure 3).

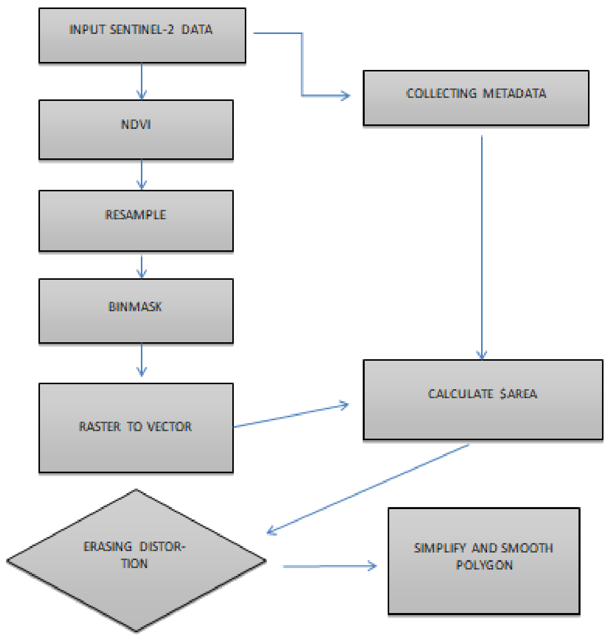

Figure 3: Algorithm flowchart.

NDVI, clipping and resampling

The first step concerns the processing of the satellite data. The NDVI ratio can be determined from the contribution of visible wavelengths and near-infrared wavelengths. We choose to start with an NDVI because this index gives a range in which it is possible to separate the vegetation surrounding the area of interest from the artificial structures of the camp. Moreover, the NDVI was computed with the well-known method as follows:

The output of this process is a Tif image composed of only one band and contains values from -1 to 1. We need to crop the latter using Rasterio library (this library permits a high performance and cleaner result when working on an extensive satellite dataset) and a mask layer that selects the area of interest suitable for our purpose (see Figure 4). This passage permits to accelerate the process and operate a well-calibrated resampling of the data. The resampling is done using the "nearest neighbour" algorithm from the GDAL library and reducing the pixel rate from 10 x 10 to 2 x 2. For the clip and the NDVI we use the Rasterio library, for the resampling the GDAL Warp tool.

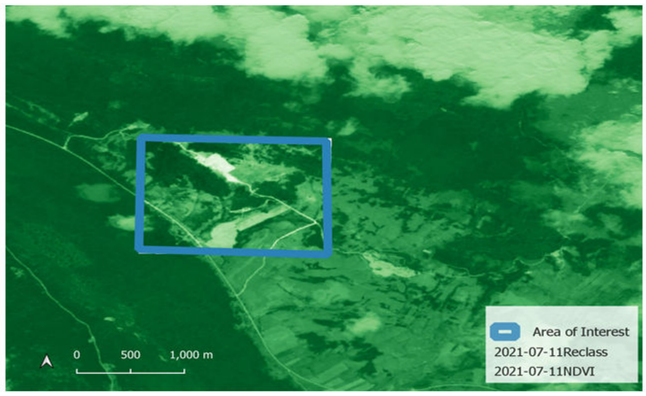

Figure 4: The NDVI raster and the resampled area of Lipa.

Creating the vector, calculate its features and erasing the distortion

To create the vector representation of the field features is necessary to isolate the range in which the structures are represented inside the layer. As the NDVI is an index, after numerous tests, we argued that the correct range is between 0 and 0.2. To reach the correct value, we try the range used to calculate the impervious rate (between 0 and 0.5), and later we decide to visually calibrate the threshold in a custom way suitable to our field. These value ranges are the ones that contain the feature of the refugee camp and help us to isolate it from the surrounding area. The resulting value is divided from the rest using a "binmask", which create a raster with a value between 0 and 1, where one contains the value isolated in the previous passage. (Figure 5).

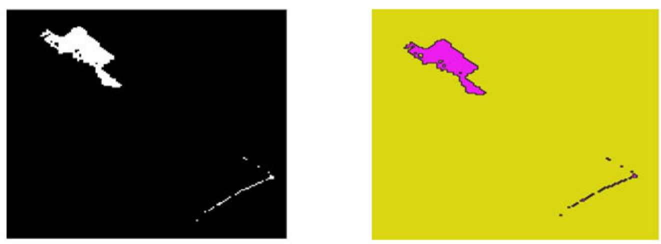

Figure 5: On the left the binmask raster. On the right, the polygon creates from it.

Now we can transform the raster into a vector using a simple "polygonise" algorithm supported in GDAL and calculate the area. In order to erase the minor distortion in the area (such as trees, pixels of the streets and null values), we filter the array of our vector, erasing the polygon with a small area value.

Sometimes in the result of our dataset, we face some distortion. The latter is a product of the NDVI threshold, and they represent large regions far from the area of interest but placed inside the framework of our dataset. For this reason, we decide to apply a spatial filter if the number of polygons inside our shapefile (create by error from the algorithm) is greater than one. The filter is composed of a mask that temporarily reduces the data frame extension, giving back a "clean" vector.

Metadata and simplification

In conclusion, the vector is completed with the addition of the metadata (the sensing date from the sentinel XML and a CSV with Lipa features) and the simplification of their shape. Our vector is elaborated from the raster pixels, and its render is rough and unsuitable for representation. To avoid this, we decide to apply at the end of the algorithm a "simplify tool" to smooth the vertex and create a more "organic" representation of the field (see the render in figure 6). Later, we add the metadata and the DateTime column to our file to have a chronological representation of the field transformation. In conclusion, every time our algorithm processes new satellite data, it adds the results into a geojson file that operates as a constantly updated and dynamic "geodataframe" (seeTable 1). Processing the satellite data, we have created a database composed of 27 vector layers showing the area length of Lipa in a specific time (see figure 6).

Table 1: Dataframe as open in QGIS.

DN	Area(m^2)	Camp name	Classification	Organization	Foundation	Nation	Continent	Datetime
1	36600	Lipa	Economic refug…	Frontex	2020	Bosnia	Europe	2020-05-22 09.5
2	30800	Lipa	Economic refug…	Frontex	2020	Bosnia	Europe	2020-07-06 9:05
3	39300	Lipa	Economic refug.	Frontex	2020	Bosnia	Europe	2020-06-260 9:05
4	40400	Lipa	Economic refug…	Frontex	2020	Bosnia	Europe	2020-07-06 9:05
5	38500	Lipa	Economic refug.	Frontex	2020	Bosnia	Europe	2020-08-20 9:05
6	49600	Lipa	Economic refug…	Frontex	2020	Bosnia	Europe	2020-12-18 9:05
7	45000	Lipa	Economic refug.	Frontex	2020	Bosnia	Europe	2020-04-27 9:05
8	54500	Lipa	Economic refug…	Frontex	2020	Bosnia	Europe	2021-06-16 9:05
9	56400	Lipa	Economic refug.	Frontex	2020	Bosnia	Europe	2021-5-2- 9:05
10	58900	Lipa	Economic refug…	Frontex	2020	Bosnia	Europe	2021-2-21 9:05

RESULTS AND DISCUSSION

This study is concentrated on mapping the changes, in terms of size, of the refugee camp of Lipa. The algorithmic flow was capable of processing the satellite data into a vector representing Lipa's growth in the last year.

The results obtained show that it is possible to monitor, with a frequency of 10 days, the spatial changes of the refugee camp using the Sentinel 2 dataset. Moreover, the calculated values do not show significant divergences in a short time (except in the crisis period when the fire takes place), providing that the data processing gives a representation in line with the actual area of the field. The area elaborated from our algorithm has resulted as a powerful instrument to reconstruct the history of Lipa in the last year. We can describe few examples of it. The camp has seen a linear growth of its area from April to July 2020, combined with its population growth from 1200 people to 1600. Later, when the population starts to decrease, passing from 1600 people to 1100 in four months, we see in the graph of the area that changes from 37200 m^2 to 72300. This fast growth of its field from December 2020 to February 2021 follows the fire and the authority's reconfiguration of the camp in response to it, highlighting clearly the emergency that took place in Lipa (see the Figure 7). As the camp structures are composed mainly of tents, their area is subject to sudden changes due to necessity. In the usual way, the number of migrants host in Lipa could change from a week to another, caused by the policies of the Serbian government.

All these characteristics are represented in our dataset, confirming the accuracy of the data collected. For example, in the last months (from March to May), we see a stabilisation of the camp's length, followed by a decrease due to the policy of the Serbian government to move the migrants to other camps in the region. The refugee and migrant crisis report from the UNICEF branch in Serbia.

The objective of this research was to underling the possibility to use the latest GIS technology and libraries to monitor the refugee camps, as in the case of Lipa. Also, it highlights the opportunity to perform data processing from Sentinel-2 satellites, which are open and accessible, giving the possibility to have an independent eye monitoring the refugee camp dynamics. The role of GIS in the field of the refugee issue is now deeply rooted. From the late '90s, this technology was used to monitor and map the refugee camp in the war fields in Africa [11,12]. At present, we see many examples of this use of GIS [13]. Primarily located in Zaatari, a refugee camp in Jordan that host refugees from the Syrian civil war. The camp opened in 2012 and represents one of the testing areas for this technology application and today is one of the largest refugee camps, both in terms of size and number of people hosted. However, all these applications concern hand drawing mapping or the use of software that provides algorithms to calculate contours or other data to use on the field. Today, automation and its exponential growth in terms of libraries, such as Rasterio, Gdal, Geopandas and programming languages as Python, represent game-changer in GIS and the thematic analysed in our paper [14,15]. We propose an application of this frontier in GIS to highlight the issues concerning refugees, as we have described in the case of Lipa.

In conclusion, the strong point of our analysis approach is related to the spatially explicit workflow and data frame, structured into a GIS dataset and fed by "dynamic data" [7]. The data collected about the camp could be compared and overlapped, highlighting what we have described before. A clear example of the ductile nature of our dataset is the graphic elaboration and comparison with the population data [16,17].

Figure 6: The final representation of our dataset.

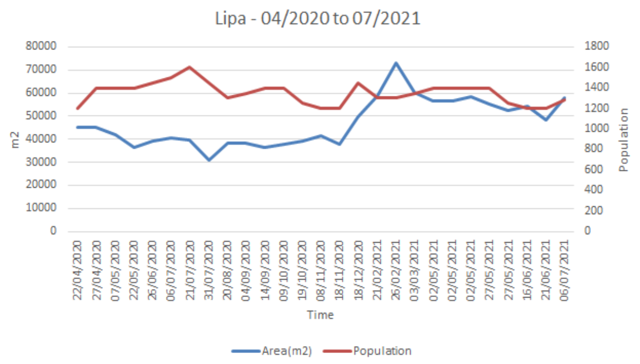

Figure 7: The graphic elaboration of the data frame.

CONCLUSION

This study could demonstrate the value of Sentinel data and the new GIS pythonic libraries to monitor and highlight critical situations regarding the refugee camps. The results revealed that using open data as sentinel is possible to mine and produce "dynamic" data about the camp. The latter could be compared, overlapped, highlighting the risk and allowing the authority to act accordingly and independently monitor the situation. Have an independent eye to evidence the situation impartially is an important step regarding the field of study of migrants. Many times, agencies as UN or Frontex has highlighted the need to have data from different sources as the authorities of the border countries.

As we live in the age of data-driven decisions, we argue that the results of the data elaboration could develop a data-driven flow for calibrating future decisions.

The call, opened during the COVID-19 pandemics, for updated data gave a boost to the application of these technologies in our study area, making GIS an effective instrument that permits evidence of a lack of facilities in bordering countries or maps the new and spontaneous camp. This view from above could also be used to compare the structures data on the ground and those given by the authorities on the field, revealing if the UNCHR guidelines are observed.

Moreover, GIS analyses and data geovisualization through cartographic representations, are a powerful communication instrument for a deep understanding of spatial and territorial dynamics of migration fluxes. Therefore, GIScience might represent an innovative and integrated approach to analyse, to communicate and to catalyse interest and on the subject.

In conclusion, the dynamic composition of GIS data allows us to go further from a mere representation. For this reason, we propose a broader approach to share this data with the public, highlighting the situations of every kind of refugee camp, from the economic to the climate ones.

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