Remote sensing digital models for supporting landscape and urban planning

The case study of the Great Prespa Lake area and the municipality of Pustec (Albania)

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Abstract - *The imminent potential accession of Albania to the European Union marks a pivotal moment for the country and its smaller municipalities, such as Pustec, located near the Great Prespa Lake. Serving as a crossroads and border among Albania, Greece, and North Macedonia, the region is moving toward integration into the European community, heralding a new era for the Albanian territory. However, the strategic development of these predominantly rural areas faces the challenge of scarce digitized data on local architectural and building heritage, resulting in a limited understanding of current urban fabric of the municipalities.*

The present paper explores how 3D technologies can serve as catalysts for multi-scale architectural design. It particularly examines the potential of three-dimensional models derived from Geographic Information Systems (GIS) and aerial photogrammetry through a comparative analysis, highlighting the advantages of an integrated approach for territorial comprehension and planning. Unlike traditional planning methods that rely on outdated or static cartography, the integration of digital 3D models enables dynamic, current, and spatially accurate representations that can better inform both preliminary and detailed planning stages.

GIS 3D models, despite limitations due to missing building data in areas like Pustec, allow for landscape-scale digital representations that facilitate visualization and understanding of the broader transnational Prespa Lake area. In contrast, aerial photogrammetry is more effective at the urban scale, offering precise mapping of architectural and building heritage across the region's municipalities.

The combined use of these technologies represents a powerful tool for constructing a foundational knowledge base to support strategic development at both landscape and urban levels, particularly in cross-border contexts. This approach underscores the importance of a comprehensive vision that addresses common territorial challenges while preserving historical and cultural heritage

Keywords - Remote sensing, landscape planning, urban planning, GIS, aerial photogrammetry.

Introduction

The Prespa region, located at the crossroads of Albania, North Macedonia, and Greece, is a unique transboundary area that includes the Great and Small Prespa Lakes and Lake Ohrid. It is home to over 50 medium-sized settlements, inhabited predominantly by indigenous populations, along with minority groups from neighboring countries. The local economy is largely based on agriculture and fishing (Çetinkaya & Kaymaz, 2005). The area's natural and cultural richness has earned it recognition as a UNESCO World Heritage site and inclusion within protected transboundary national parks (Muslli, 2016).

The presence of significant natural (lakes, forests, and mountains) and anthropogenic (customs borders and cultural boundaries) frontiers has deeply influenced the development of these communities (Makartsev et al., 2016). In particular, the Albanian side of the region faces pressing issues such as depopulation, driven by post-1990s border openings, distance from urban centers, and limited opportunities for youth. These dynamics have fueled ongoing emigration toward larger cities or abroad (Arrehag et al., 2006).

Environmental pressures have also intensified, notably the visible reduction in the lake's size over the past three decades. This change has significantly altered both the physical landscape and the functional relationship between human settlements and the lake ecosystem (Kuzmanoski et al., 2022).

In this evolving context, Albania's upcoming accession to the European Union raises new opportunities and challenges for the entire region, including the opening of borders and the free movement of goods and people. It offers prospects for cross-border cooperation, economic integration, and enhanced mobility, while also demanding alignment with EU spatial planning standards and addressing the complex dynamics of a historically fragmented border landscape.

To address these evolving dynamics, it is essential to define spatial strategies capable of reactivating local interest while preserving the region's natural and cultural assets. This includes enhancing environmental protection, valuing traditional practices and heritage, and improving accessibility, mobility, and services. Such integrated planning can strengthen the human-environment system and promote sustainable tourism and local development (Vagiona & Mylopoulos, 2005).

However, planning in such contexts requires a reliable and updated knowledge base, something currently lacking due to the scarcity of digitized information on the urban fabric. This absence hampers the formulation of coherent development strategies and underscores the importance of spatial mapping and data integration.

The present paper investigates digital workflows for generating low-cost three-dimensional representations of the Prespa region, focusing on the municipality of Pustec. It explores the combined use of GIS-derived 3D terrain models and UAV-based aerial photogrammetry to support landscape and urban planning at multiple scales. The study stems from field observations and data collected during the international Ph.D. workshop "Intersecting Landscapes" (Polis University, Tirana, November 2023), which focused on identifying new spatial visions for this cross-border region.

Literature Review

Geographic Information Systems for landscape and urban planning

Geographic considerations have long played a critical role in decision-making processes, with cartography and spatial data visualization serving as foundational tools across human activities (DeSanctis, 1984; in Keenan, 2008). The computational advancements of the 1960s enabled the evolution of traditional cartography into the first Geographic Information Systems (GIS) (Tomlinson, 1969). With the rise of personal computers in the 1980s and their increased capability in the following decade, GIS applications expanded significantly, becoming more accessible through a range of software platforms (Keenan, 2008).

Today, GIS is a mature, versatile tool used in a wide array of sectors such as urban and territorial planning, environmental monitoring, agriculture, infrastructure, public health, defense, tourism, and beyond, facilitating the analysis and modeling of spatial and temporal phenomena (MacEachren, 2000; Fistola, 2011). These systems rely heavily on remote sensing data, especially aerial and satellite imagery processed via photogrammetry, typically at a resolution of 1 meter per pixel (Skidmore, 2022).

GIS platforms come in many forms, each designed to support different types of applications: commercial software like ArcGIS (ESRI) enables management of complex datasets, while more accessible tools such as ESRI ArcView and MapInfo are geared toward decision-making (Keenan, 2008). Among open-source solutions, QGIS is particularly noteworthy for its flexibility, rich plugin ecosystem, and widespread use in academic and professional contexts. With the expansion of the internet, web-based GIS services have emerged, providing online access to distributed geodata (Tao, 2001). Applications like Google Maps, Google Earth, and MapQuest offer user-friendly 2D and 3D visualization tools. However, they lack the analytical depth and integration capabilities of full-featured desktop GIS platforms (Keenan, 2008).

Despite these advancements, GIS still faces limitations, particularly regarding the accuracy and update frequency of online datasets in under-digitized or remote regions. Inconsistent or outdated information can hinder planning efforts (Skidmore, 2002).

To address these gaps, building information datasets created from high-resolution aerial photogrammetry and integrated into GIS platforms offer a promising complement. These methods allow for precise spatial representations of terrain, infrastructure, and the built environment, thus equipping planners and policymakers with reliable data for more effective and context-sensitive land and urban resource management.

Unmanned Aerial Vehicle (UAV) photogrammetry for landscape and urban surveying

In recent decades, remote sensing has increasingly become a prevalent methodology in the field of extensive territorial data acquisition, providing significant resources to cartography, as previously mentioned, such as GIS platforms. Traditional forms of remote sensing generally rely on acquiring measurements from satellites or manned aircraft and the post-processing of these for the creation of orthomosaics and Digital Elevation Models (DEMs).

Based on the specific objectives to achieve, various types of DEMs can be generated, including Digital Terrain Models (DTM), which represent only terrain elements; Digital Surface Models (DSM), which include both terrain and man-made or vegetal elements, and Digital Building Models (DBM), which encompass only building elements (Gorički et al., 2017).

However, as noted by Whitehead & Hugenholtz (2014), often the data acquired from conventional remote sensing platforms *"do not have the resolution and operational flexibility to address [...] effectively or affordably" (p. 70))* the challenges that more detailed work may require. As a result, within the field of remote sensing, there has been a recent emergence and rapid spread of technologies based *on unmanned aerial vehicles (UAVs) and systems (UASs) or remotely piloted aircraft.*

Furthering the discourse initiated by Whitehead & Hugenholtz (2014), *"UASs are emerging as flexible platforms that, in many cases, have the potential to supplement and/or complement traditional remote sensing methodologies".* Its applications span various scales, from territorial to urban and individual buildings. UAS may be equipped with Light Detection and Ranging (LiDAR) technology or RGB, spectral, or thermal cameras. Generally, the photogrammetry workflow utilizes a Structure from Motion (SfM) reconstruction process with Multi-View Stereo (MVS) RGB images (Smith et al., 2015).

LiDAR and photogrammetry are two sophisticated aerial surveying methods, each with unique features suited for different application contexts. The choice between LiDAR and photogrammetry ultimately depends on the project's specific goals, environmental conditions, detailed requirements, and budget constraints. LiDAR uses laser pulses to measure distances between the sensor and the ground, excelling in high-accurate data collection even under poor visibility or dense vegetation, making it ideal for projects requiring accurate topographical details, at the expense of a relatively high cost for the equipment (Fernández et al., 2021, cited in Kovanič., 2021). On the other hand, photogrammetry stands out for its accessibility, ease of use, and visual data quality, especially in well-lit conditions. For this paper, focusing on landscape and urban surveys through accessible equipment and automated and semi-automated methodology rather than absolute precision, we will delve into UAV photogrammetry.

According to Picon-Cabrera et al. (2021), *"the automatic reconstruction of urban 3D models has turned out to be one of the most growing sources of UAS photogrammetric research in the last two decades"* (p. 2). The efficiency of the photogrammetric process, particularly when derived from aerial flights, is valued for its high degree of automation and the potential high quality of its outputs.

As stated by Adami et al. (2023), *"the size of the surveyed [...] area, and the goals of the survey, drive the choice of the most appropriate technical solutions for the survey, like the type of drone, the camera and its resolution, the quality and mode of image acquisition, the photogrammetric processing parameters, and the georeferencing approach"* (p.19). Flight planning optimizes survey times, reduces operator errors, and ensures the acquisition of predefined results by setting parameters like flight area confinement, flight path pattern, overlap percentages between shots, drone type, terrain follow option, flight altitude, UAV speed, flight duration, and battery usage (Śledź & Ewertowski, 2022). The flight altitude is determined based on the desired spatial resolution, represented by the Ground Sampling Distance (GSD), which is the ground distance between two adjacent image pixels. Typically, a GSD of 1-2 cm/pixel is desired for detailed landscape and urban surveys, compared to the 1m/pixel resolution typical of conventional remote sensing.

The SfM process outputs include point clouds, classified point clouds, textured mesh models, orthomosaics, Digital Elevation Models (DEMs), and contour lines. From the point cloud, portions can be classified through more or less automated workflows, allowing filtering specific interest classes and going further processing only the

Fig. 1: Quadrants of interest for the Great Prespa Lake. In red, is the specific area of interest.

interested one to achieve specific outputs, as the different types of DEMs mentioned earlier. As noted by Adami et al. (2023), *"the density of the point cloud generated by UAS photogrammetry varies based on flight altitude and camera resolution"* (p. 19). Precision and accuracy of the results depend on the possible combination with a GNSS terrestrial survey (measuring the coordinates of so-called Ground Control Points) or Real-Time Kinematic (RTK) technology and are gauged by comparing the coordinates of specific reconstruction points (Check Points) with their actual coordinates (Nex & Remondino, 2013; Štroner et al., 2020).

In Section 3.2, it will be shown how to structure this set of variables to develop various workflows useful for the surveying of landscapes and urban areas. This is aimed at producing outputs that might be beneficial to decision-makers in planning strategies for conservation, enhancement, and service implementation in the Prespa Lake region and, in particular, for the municipality of Pustec.

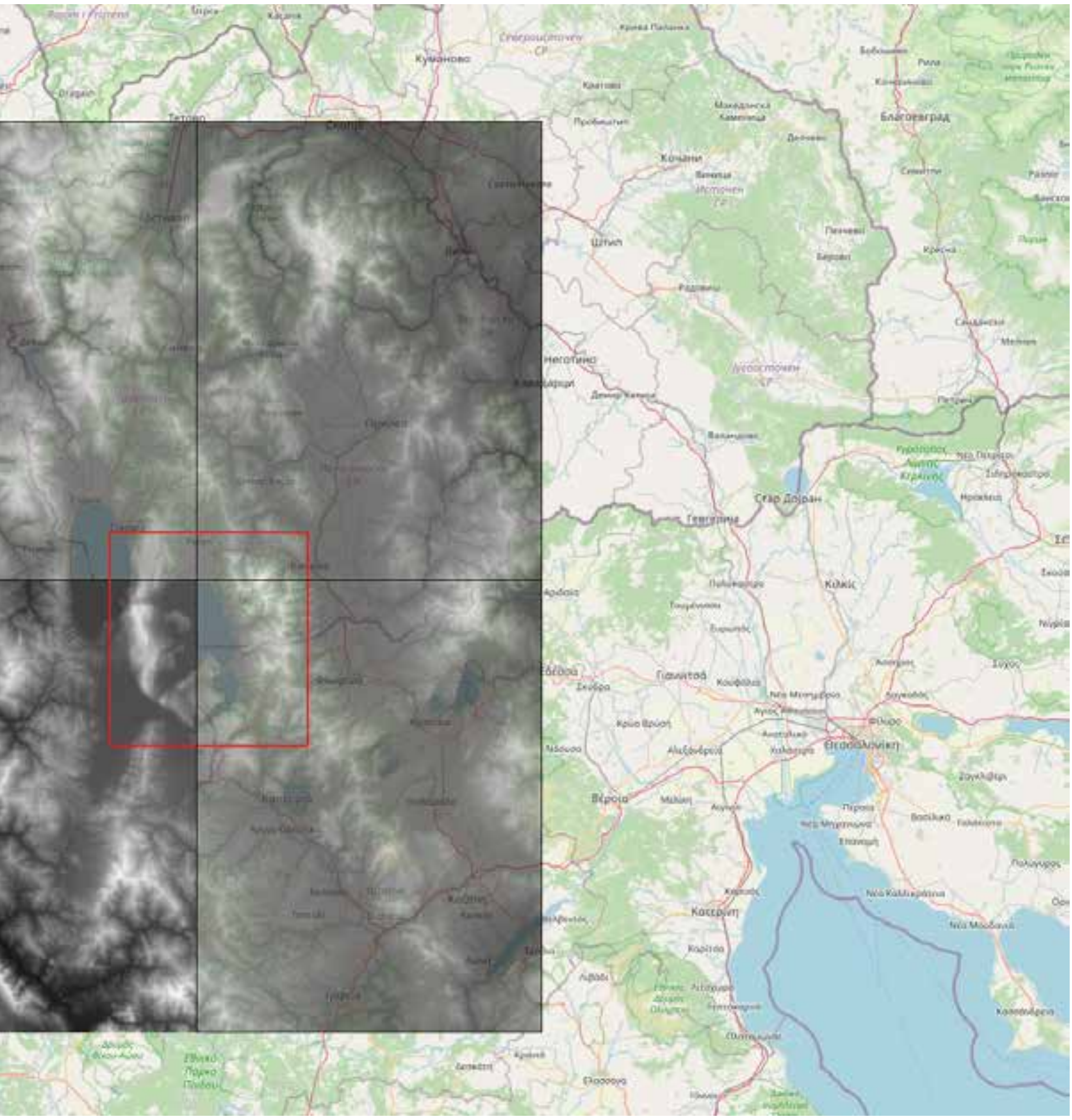
Tools and methodology

GIS models for strategic environmental and urban planning

To support the preliminary phase of the study and the strategic proposal, the effective utilization of GIS archives can offer valuable resources that third parties have already digitized. These resources may include cartographic, physical, geological, and meteorological analyses, as well as demographic flows and processes, from a bi-, tri-, and even four-dimensional perspective with the incorporation of the temporal variable.

Focusing on GIS tools, particularly those derived from remote sensing technologies, interesting opportunities arise. Despite limited accuracy in metric data, these tools can provide invaluable resources for communicating the current state of environments and human settlements. This is particularly useful for the analysis phase and for communicating preliminary strategic intentions before design.

To analyze terrain elevation data, we introduce the first workflow, which involves the use of the open-source software QGIS. Initially, it is advisable to set the appropriate reference system, such as WGS84 Pseudo Mercator EPSG:3857. QGIS natively allows for the display of satellite orthophotos with variable resolution depending on the scale and zoom settings used for navigation in the interface. It also provides access to a wide variety of informational layers, either built-in or importable using our own



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data or via dedicated plugins. It is crucial to ensure that all layers used share the same coordinate system to maintain consistency in the projection of different data.

Among the most useful plugins, *'QuickMapServices'* derves mention for enabling map navigation through the OpenStreetMaps (OSM) interface, while *'SRTM-Downloader'* is valuable for accessing and utilizing existing elevation data. *'SRTM'* refers to the "Shuttle Radar Topography Mission," which, as reported on the NASA website (National Aeronautics and Space Administration), "during the STS-99 mission (February 11-22, 2000), collected topographic data over nearly 80% of Earth's land surfaces, creating the first-ever near-global topographic maps of Earth."

The obtained DEM is a raster image displaying the quadrants of interest; the grayscale pixels represent the elevations of individual 30m² cells, following the SRTM-30 standard. It is possible to crop this area

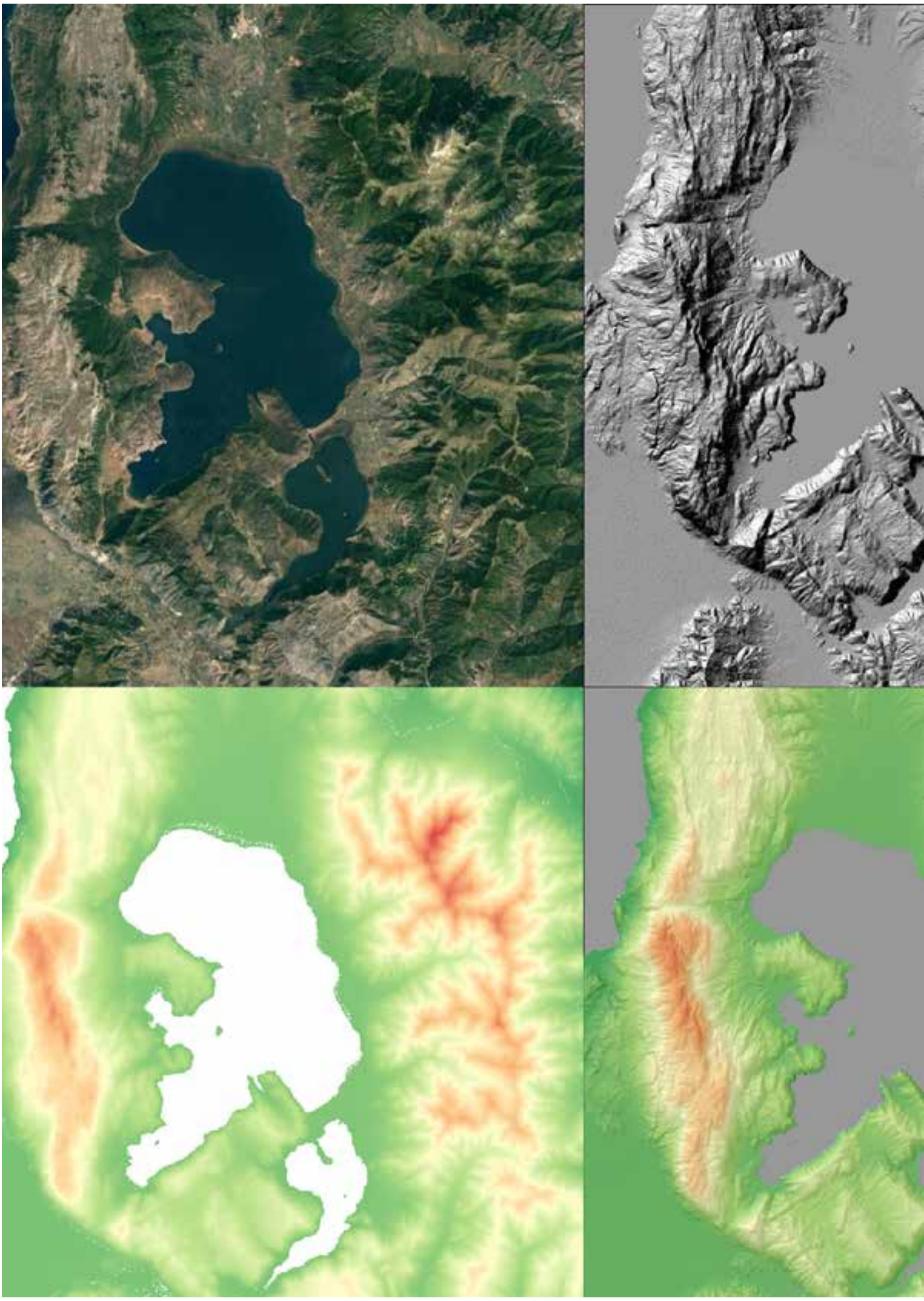
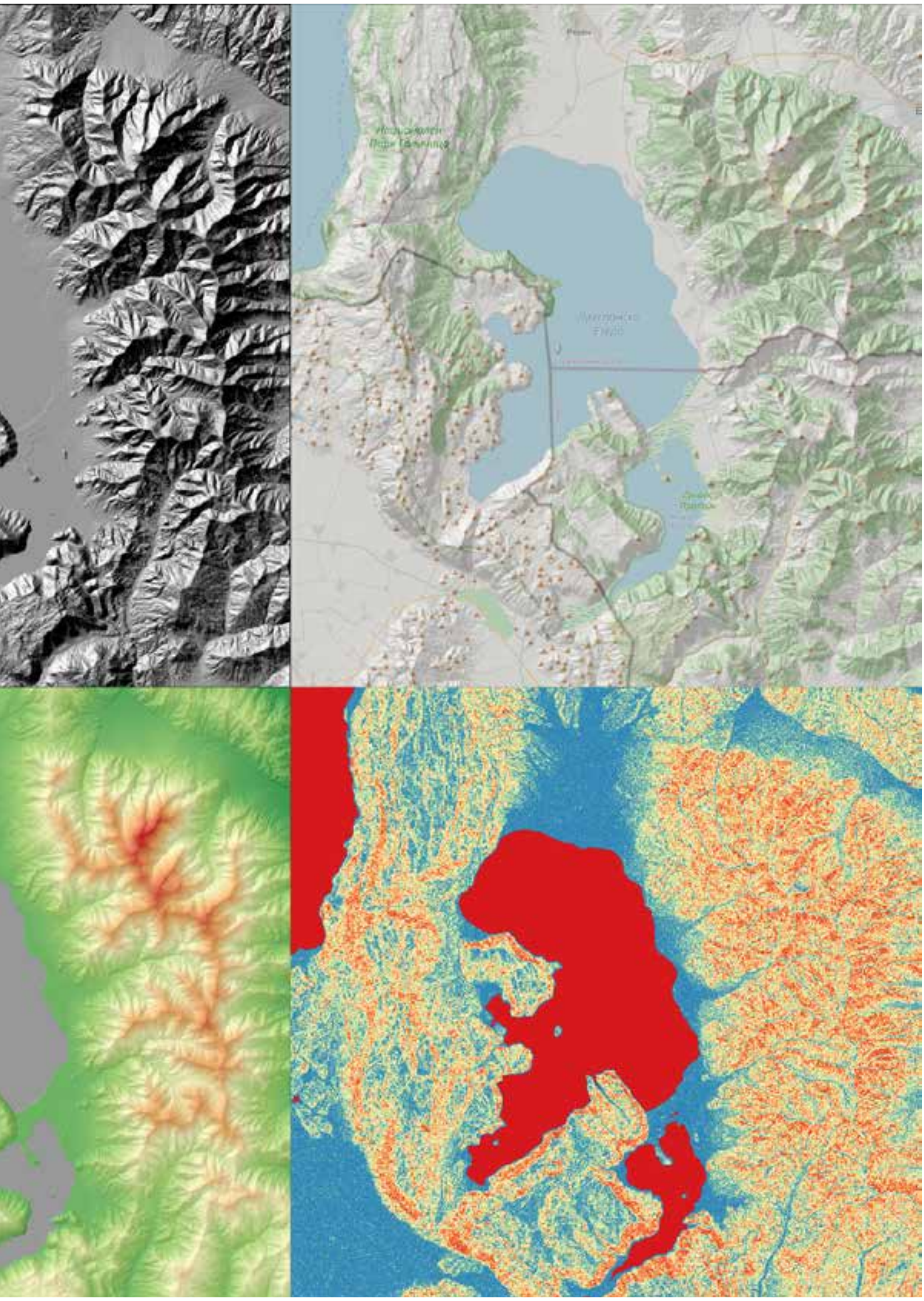


Fig. 2: GIS analysis on the Great Prespa Lake area. Above, from the left: satellite map, hillshade map, OSM map. Below, from the left: DEM, DEM + hillshade, slopes.

further to focus specifically on the Great Prespa Lake, as shown in Figure 1. The $30m^2$ limit is due to open access reasons of the DEM data, which, however, cannot go below 10m for international security reasons unless justified by operational needs. As reported in Figure 2, the visualization and reading of elevation data are facilitated using customizable color scales and the possible overlay of various layers—such as satellite images, DEM, OSM maps, and hillshade visualizations—through skillful use of the transparency tool. Such representations allow for effective communication of the model's characteristics depending on the specific message to be conveyed.

The elevation data provided by DEMs enable the creation of three-dimensional models and the transformation of raster images from various layers into textures, as shown in Figures 3 and 4. These models can be viewed, navigated, or exported as



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images or 3D models using the native commands or specially designed plugins like qgis2threejs. The ability to export 3D models opens up opportunities for conducting analyses or modifications on software dedicated to specific 3D modeling tasks.
It should be noted that high resolution on a large scale can pose a complex technical challenge and sometimes be prohibitive. The resolution of the 3D model's texture depends on the scale factor of the view, and it is not possible to achieve both a model with extensive territorial coverage and high texture resolution simultaneously, due to computational issues that could lead the software crashing and failing to export the model.
To address the problem of exporting 3D models from QGIS, an alternative methodology based on the BlenderGIS plugin for Blender, an open-source software specifically designed and used in the field of three-dimensional modeling, is proposed. The issue of the relationship between geometric extension and texture resolution observed in the previous workflow remains, but, through the zooming tool used for acquiring image data from satellite resources, BlenderGIS allows for slightly better texture image resolutions.
The first step is to define the project's coordinate system. It's essential to ensure consistency between the coordinate system in use and that of the source data. Notably, in this case, the plugin draws data from the Web Mercator system, which can introduce significant local distortions. For accurate measurements, it is advisable to use coordinate systems and projections optimized for specific geographic regions, often represented by national grids. Since the plugin does not automatically reproject maps between different coordinate systems, it may be necessary to prepare the map in external software like QGIS and import the raster with the already reprojected DEM into BlenderGIS.
The next step involves importing the basemap limited to the area of interest. The basemap, viewable as a satellite image obtained from one of the engines like Google, ESRI, OSM, and Bing, has a resolution dependent on the zoom level of the view and, at a certain point, will be "printed" at a certain resolution. The higher the zoom value, the higher the resolution and the more numerous the satellite data tiles to be mosaic, with the potential for the process to collapse in case of excessive dimensions. For this reason, and the purposes of this paper, this workflow was chosen to create

Fig. 3: The Great Prespa Lake 3D model from QGIS (through the qgis2threejs exporter plugin), with satellite-derived texture. *source/ QGIS plugin qgis2threejs exporter graphic extrapolation.*

Fig. 4: The Great Prespa Lake 3D model from QGIS (through the qgis2threejs exporter plugin), with DEM + OSM derived texture. *source/ QGIS plugin qgis2threejs exporter graphic extrapolation.*

two distinct models: the territorial area of Great Prespa Lake (Figure 5) and the urban area of the municipality of Pustec (Figure 6).
The basemaps are now transformed into three-dimensional form through the integration and processing of DEM-STRM30 elevation data. Access to this information is provided by BlenderGIS itself by entering an API key, which can be obtained for free from OpenTopography (OpenTopography, 2021) for non-commercial or academic use. It is important to note that excessive zooming can cause the software to crash.
BlenderGIS enables the study of topological features such as elevation and slopes, creating a new associated material that features customizable color scales based on the analytical aspects one wishes to highlight. Although OpenStreetMaps offers the potential to extract features such as roads and buildings, data for this specific area are unavailable, leaving us without relevant information. Given the need to depict the current urban fabric of Pustec for preliminary communication and the absence of concrete and reliable data on building heights at this initial stage, it was decided to develop a script for Grasshopper (a visual programming language plugin for Rhinoceros) to provide an intuitive representation of the current state. Initially, using Rhinoceros, the terrain mesh derived from BlenderGIS was split with curves traced following the buildings' outlines from an aerial perspective. This process yielded two sets of meshes: the terrain mesh and the building meshes, particularly representing the roofs. The script depicted in Figure 7 extrudes the building meshes by a random height ranging from 5.0 to 8.0 meters, mirroring the assumed average height of the buildings in the area. The outcome is an approximate three-dimensional model of Pustec's buildings, distinguishing residential from production or service buildings based on empirical evaluations (Figures 8 and 9). This outcome offers a swift and highly cost-effective solution as a foundational work base to understand the plausible current state of settlements for which there is no downloadable information from online portals, as in the case of Pustec. It also serves as a valuable tool for communicating potential future project intentions, particularly considering that it is a rapid, low-cost approach developed remotely by leveraging open-access data from online GIS platforms, requiring minimal manual effort.
Should genuine interest arise in developing an urban, infrastructural, or environmental plan for a specific area, it will then be necessary to provide a far more reliable three-dimensional work base. In such instances, an essential and inevitable task will be field surveying using detailed remote sensing techniques through UAS, such as Lidar or aerial photogrammetry.

Fig. 5: The Great Prespa Lake 3D model from Blender (through the BlenderGIS plugin), with satellite-derived texture.

source/ Blender graphic extrapolation.

Fig. 6: Pustec 3D model from Blender (through the BlenderGIS plugin), with satellite-derived texture.

source/ Blender graphic extrapolation.

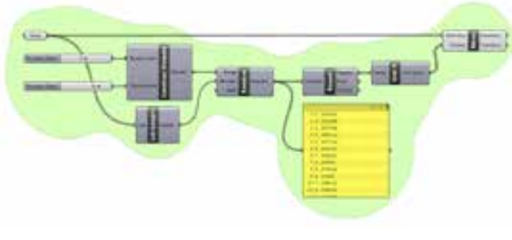

Fig. 7: The Grasshopper script used to reconstruct the buildings.

source/ Blender graphic extrapolation.

Aerial photogrammetry models for urban planning design

Mapping the current state of the urban fabric could be useful, if not fundamental, in phases after the preliminary strategic one. In the absence of data on elevations, the number of floors, and the types of buildings in an urban complex, an effective, accurate, and sometimes economical solution could be aerial surveying using UAS technologies.
Focusing on the case study of the urban area of the municipality of Pustec, a technical comparison between two possible planned aerial survey strategies for photogrammetry aim is presented below.
For this purpose, the Dronelink software solution was chosen, which offers a web application for flight mission planning on PC and a dedicated smartphone app for planning, connecting with the drone, and controlling it during flight. Dronelink stands out for the variety of its features, which vary according to the chosen license plan. For this case, the "growth plan" was chosen, which proved ideal for planning in areas with flight modes at variable altitudes depending on the terrain.
This discussion will analyze two missions that focus on the same area but differ due to the type of *UAS* chosen and, consequently, the characteristics of the onboard camera. Therefore, some specific parameters will be proposed during flight programming for one case or the other. The selected *UAV models* are *two DJIs* at the entry and medium levels: the *DJI MINI 2* and the *DJI Mavic 3* Enterprise (M3E), the latter equipped with RTK technology that allows accurate georeferencing of shooting positions.
After creating a new mission and selecting a destination repository, public or private, flight planning can begin. Maps that will compose the main mission are then drawn, defining their respective extensions with care not to exceed 10 hectares of covered area to avoid potential application dysfunctions. As illustrated in Figure 10, the urban

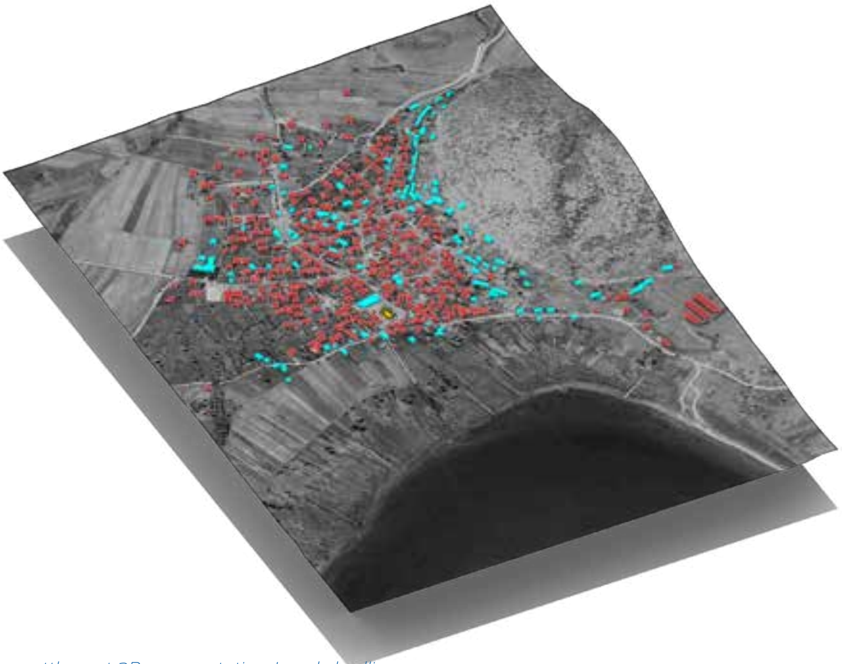

Fig. 8: Pustec settlement 3D representation. In red: dwellings; blue: production buildings, yellow: services.

source/ Rhinoceros graphic extrapolation.

Fig. 9: Pustec settlement 3D representation, final output.

area of Pustec was divided into 6 maps, partially overlapped, to facilitate the camera alignment of adjacent maps in the photogrammetric processing phase. The maps of the two missions may have slight differences between them, designed to optimize the flight plan of the specific mission.
Tables 1 and 2 illustrate the configurations set for the missions conducted with the *DJI MINI 2* and the *DJI Mavic 3* Enterprise, respectively. The settings were selected to adapt to the specific requirements of the survey and to make the most of the capabilities of the two different drones.

One of the initial strategic decisions was to activate the terrain follow mode, which allows for programming flights at a constant height relative to the ground, based on elevation maps provided by *ESRI.* This approach ensures a uniform Ground Sample Distance *(GSD)* across the entire area of interest, set at approximately 3 cm per pixel. The flight height necessary to achieve this *GSD* was calculated based on the specifications of each drone's camera, resulting in two different flight altitudes for the *MINI 2* and the *M3E*.
The drone's speed was set to 16 km/h to prevent excessively rapid flights that could compromise the clarity of the photos. The flight path configuration was chosen to be grid-like rather than linear, to ensure complete and consistent coverage of the area, thereby optimizing data acquisition in both travel directions. Additionally, both the vertical overlap between shots and the lateral overlap between strips were set at 80%, following best practices in aerial photogrammetry.
Finally, instead of orienting the camera in the nadir direction (directly downward), a tilt angle of 60 degrees relative to the horizon was preferred. This choice aims to improve the survey of the vertical surfaces of buildings, crucial for an accurate three-dimensional reconstruction of the built environment.
Figures 11 and 12 refer to the mission with the *M3E* and offer a two-dimensional and three-dimensional preview of the flight plan.
In Figure 11, the flight path designed for the six different maps can be observed, with a particular focus on the path of the first map, including a pin indicating the starting point and a red dot marking its conclusion. At the end of the survey for each map, the subsequent behavior of the drone can be programmed, choosing whether to return it to the base or proceed directly to the starting point of

source/ Rhinoceros graphic extrapolation.

Fig. 10: The six maps composing the flight mission. source/ Dronelink graphic extrapolation.

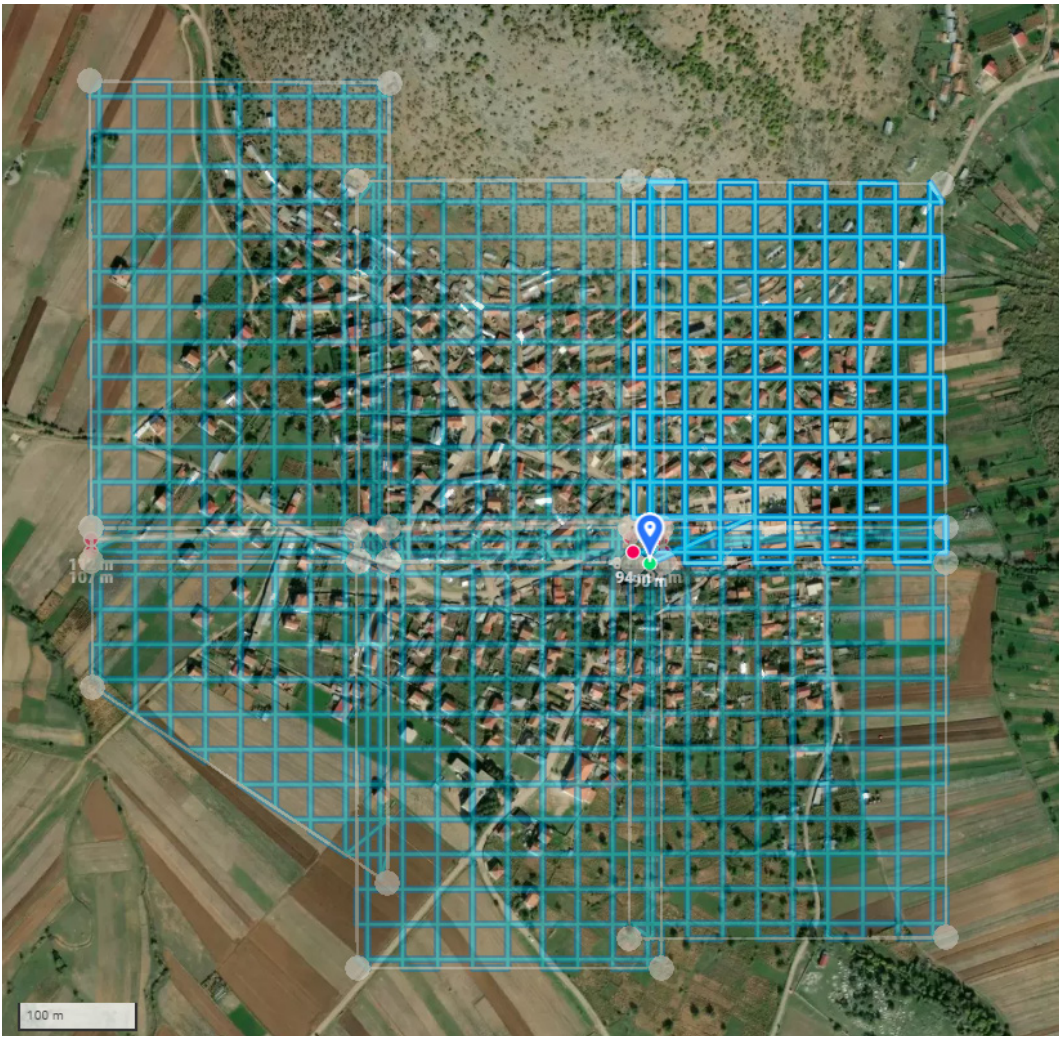

Fig. 11: M3E bi-dimensional flight path. Focus on the first map. source/ Dronelink web app graphic extrapolation.

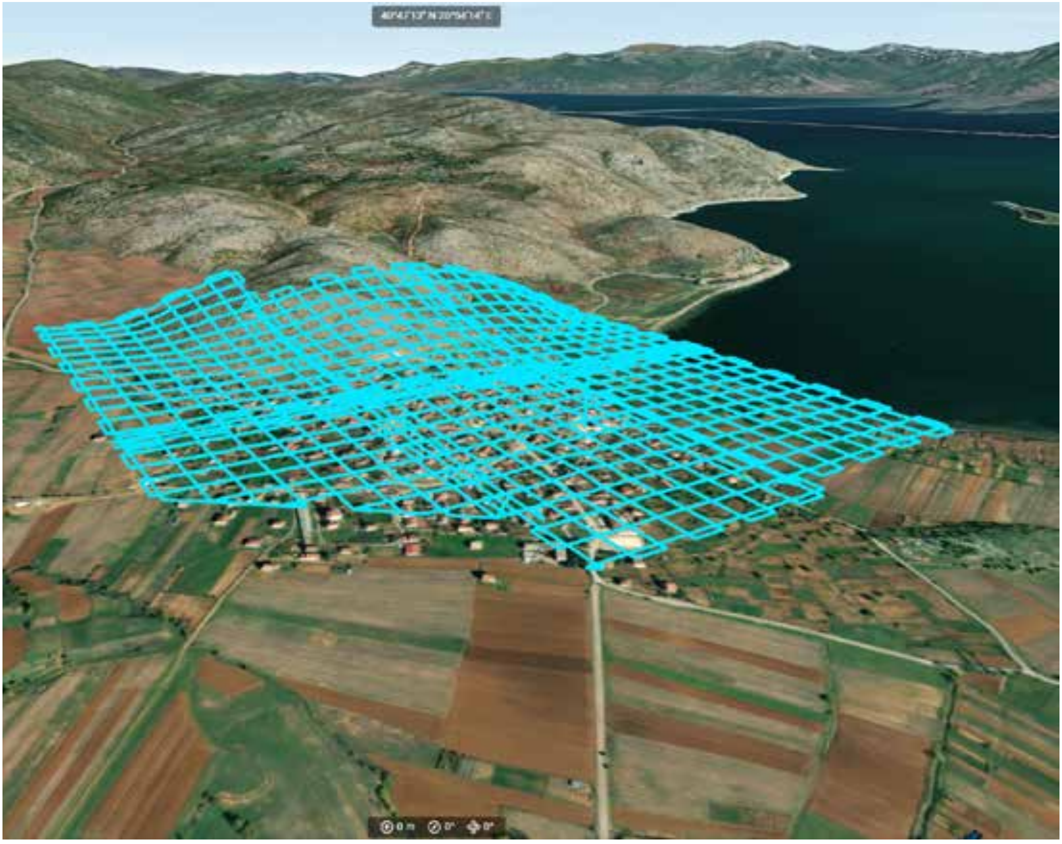

Fig. 12: M3E three-dimensional flight path. *source/ Dronelink web app graphic extrapolation.*

Mission	Altitude reference	Altitude AGL (m)	Flight speed (km/h)	Path pattern	Image frontal overlap	Image lateral overlap	Horizon angle	GSD (cm/pix)
DJI Mini 2	Terrain follow	70	16	Grid	80%	80%	-60°	2.87
DJI Mavic3E		90						2.78

Map	*Hectares (ha)*	*Flight duration*	*N° batteries*	*Photos*
1	8.2	00:33:15	3	425
2	8.9	00:36:16	3	480
3	9.4	00:36:59	3	482
4	8.1	00:33:31	3	419
5	9.7	00:39:19	3	508
6	5.3	00:24:50	2	286
Total	46.3	03:23:32	14	2600

Map	*Hectares (ha)*	*Flight duration*	*N° batteries*	*Photos*
1	8.2	00:27:14	2	267
2	9.0	00:29:44	2	298
3	9.3	00:30:25	3	309
4	8.1	00:26:22	2	267
5	9.7	00:33.19	3	339
6	5.3	00:19:38	2	182
Total	46.3	02:46:59	12	1662

Tab. 2: DJI MINI 2 mission estimate. *source/ Dronelink mission estimate.*

the next map. This operational flexibility allows for optimizing the efficiency of flight sessions.
In case of battery depletion, the mission is automatically interrupted, allowing the drone to be recalled for battery replacement. Once replaced, the drone is capable of resuming flight exactly from the point of interruption, thus ensuring the continuity and integrity of the survey. The "mission estimate" feature provides useful predictions regarding the duration of missions, the number of batteries required, and the number of photographs that will be captured, allowing for accurate and predictable planning of operations.

Tables 2 and 3 present a detailed account of the settings and expected results for the missions conducted with the *DJI MINI 2* and the *DJI M3E*, respectively.
The estimate of battery usage for survey missions with the *DJI MINI 2* and *M3E* drones is based on a maximum expected autonomy of 15 minutes per flight, to ensure a safe return to base. This estimate varies depending on weather conditions: in the presence of stable wind, autonomy might exceed 15 minutes, while in strong wind conditions, energy consumption would increase to maintain drone stability, consequently reducing battery life.

Tables 1 and 2 provide a forecast of survey times and battery consumption for each survey map, considering also, for the total count, transfers between the various start and end points of the sub-missions, without including the necessary breaks for battery replacement.
The comparative analysis of the two strategies highlights that the time required for the survey campaign with the *DJI MINI 2* is 23% higher than that required with the M3E, a difference not significant in terms of total time (about 3 and a half hours). It is also interesting to note the estimated number of photographs, which, with a 56% increase for the *MINI 2,* would lead to an extension of data processing times in the post-survey phase.
The most significant distinction between the two methodologies concerns the accuracy of the image geolocation. The *M3E*, thanks to the support of *RTK* technology, guarantees high accuracy in the georeferencing of each shot. In contrast, with the DJI *MINI 2*, a *GNSS* (Global Navigation Satellite System) ground survey is necessary to compensate for the unreliability of the *GPS* coordinates associated with the photos. In this case, it will be necessary to place visible targets from 70m on the ground and beat their geographic coordinates with *GNSS* tools such as antennas or total stations. The *GNSS* survey could be useful in the case of the strategy with the Mavic 3 Enterprise almost exclusively as a check on the accuracy of the georeferencing information of the cameras, however, it is not as fundamental as in the case of the *MINI 2*. This is the major difference between the two survey strategies.
At the end of the survey campaign, the collected data will be processed using Structure from Motion *(SfM)* software for image alignment, point cloud generation and classification, as well as 3D mesh creation for the production of digital surface models *(DSM)*, terrain models *(DTM),* or building models *(DBM).* The process will conclude with the texturization of the models to obtain detailed three-dimensional representations of the surveyed area.
This approach will thus enable the provision of comprehensive three-dimensional data on the urban area of the municipality of Pustec to urban planning decision-makers.

Conclusions

The study explored the potential of remote sensing technologies, specifically GIS and UAV photogrammetry, to support spatial analysis and planning at both urban and landscape scales in data-scarce contexts such as the municipality of Pustec and the broader Great Prespa Lake region.
It demonstrated the effectiveness of open-source platforms like QGIS and BlenderGIS in generating Digital Elevation Models (DEMs) using publicly available datasets. By employing visual processing techniques like color gradients and transparency effects, these tools enabled the creation of multi-layered two-dimensional and three-dimensional representations. In the absence of detailed data on building heights, a scripting-based method was implemented to estimate building volumes based on hypothetical empirical values, resulting in a preliminary yet functional urban model to support strategic planningdiscussions.
To address the lack of information on building heights and typologies in the urban fabric of Pustec, the research proposed a comparative analysis between two UAV photogrammetric survey strategies. These involved the planning of flight paths aimed at producing high resolution Digital Surface Models (DSMs) and Digital Building Models (DBMs). The strategies differed in terms of UAV models used, and their respective advantages and limitations were assessed regarding flight duration, challenges in data processing, and the necessity to complement aerial photogrammetry with terrestrial GNSS surveys.
The presented methods are highly relevant for professionals and institutions involved in conservation, enhancement, or redevelopment efforts in areas like the Greater Prespa Lake or under-documented municipalities such as Pustec. The resulting digital models can function as dynamic, continuously updatable databases supporting long-term environmental and urban monitoring.
Integrating these approaches into local governance processes can enable more agile, responsive, and context-sensitive planning. Supported by open-source tools and periodic UAV-based data acquisition, the system remains cost-effective, adaptable, and scalable. Furthermore, the replicability of these integrated methodologies makes them applicable to other rural or cross-border regions with limited geospatial data, offering a solid foundation for territorial diagnostics, strategic planning, and funding applications.
This study lays the groundwork for more structured, evidence-based planning workflows in data-poor environments, paving the way for future research and implementation in similar contexts.

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