Geoconexões

MATERIALIZING THE LANDSCAPE: DRONES, GEODESY, AND 3D PRINTERS IN A VIABLE AND ECONOMIC SOLUTION FOR 3D MODELING

MATERIALIZANDO A PAISAGEM: DRONES, GEODÉSIA E IMPRESSORAS 3D EM UMA SOLUÇÃO VIÁVEL E ECONÔMICA PARA A MODELAGEM 3D

MATERIALIZANDO EL PAISAJE: DRONES, GEODESIA E IMPRESORAS 3D EN UNA SOLUCIÓN VIABLE Y ECONÓMICA PARA LA MODELACIÓN 3D

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ABSTRACT

In recent years, environmental modeling has become increasingly crucial for understanding and mitigating the impacts of human activities on the environment. However, traditional methods for environmental mapping, primarily those of physical understanding, face challenges related to accuracy, time, and cost. In this sense, this work aimed to evaluate the technical feasibility of altimetric mapping and 3D model construction using drones, precision geodesy, and 3D printing as an extremely effective and low-cost alternative for environmental modeling. The study focused spatially on the boundaries of the IFRN/Campus Macau terrain. The study was conducted in five stages: I) Literature review; II) Geodetic survey (GNSS); III) Aerophotogrammetric survey; IV) Processing of geodetic and aerophotogrammetric data; and V) 3D printing. A protocol was obtained for the elaboration with high vertical and horizontal accuracy of the Digital Surface Model (DSM), orthomosaic, and 3D model (virtual and physical) of the mapped environment. Regarding the 3D model, its printing allowed for a perfect understanding of the geomorphology of the mapped environment and the existing physical structures. The applied technique could be useful in various areas, such as enhancing the planning stage in civil construction, architecture, and environmental studies. Also becoming a great ally in future geomorphological and tactile cartography studies.

KEYWORDS: geoprocessing; remotely piloted aircraft; environmental mapping; digital elevation model; 3D printing.

RESUMO

Nos últimos anos, a modelagem ambiental tem se tornado cada vez mais crucial para compreender e mitigar os impactos das atividades humanas sobre o meio ambiente. No entanto, os métodos tradicionais para realizar o mapeamento

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ambiental, principalmente o de entendimento físico, enfrentam desafios relacionados à precisão, tempo e custo. Neste sentido, este trabalho teve por objetivo avaliar a viabilidade técnica de mapeamento altimétrico e construção de maquete 3D, por meio do uso de Drone, geodésia de precisão e impressora 3D como uma alternativa extremamente eficaz e de baixo custo para modelagem ambiental. O trabalho teve como recorte espacial experimental os limites do terreno do IFRN/Campus Macau. O estudo foi realizado em cinco etapas: I) Levantamento bibliográfico; II) Levantamento geodésico (GNSS); III) Levantamento aerofotogramétrico; IV) Processamento dos dados geodésicos e aerofotogramétricos; e V) Impressão 3D. Obteve-se um protocolo para elaboração com alta acurácia vertical e horizontal do Modelo Digital de Superfície (MDS), ortomosaico e maquete 3D (virtual e física) do ambiente mapeado. Sobre a maquete 3D, a sua impressão, permitiu o perfeito entendimento da geomorfologia do ambiente mapeado e das estruturas físicas existentes. A técnica aplicada poderá ser útil em diversas áreas, como por exemplo, potencializar a etapa de planejamento na construção civil, arquitetura e estudos ambientais. Se tornando também, grande aliada em futuros estudos geomorfológicos e de cartografia tátil.

PALAVRAS-CHAVE: geoprocessamento; aeronave remotamente pilotada; mapeamento ambiental; modelo digital de elevação; impressão 3D.

RESUMEN

En los últimos años, la modelización ambiental se ha vuelto cada vez más crucial para comprender y mitigar los impactos de las actividades humanas sobre el medio ambiente. Sin embargo, los métodos tradicionales para llevar a cabo el mapeo ambiental, especialmente el de entendimiento físico, enfrentan desafíos relacionados con la precisión, el tiempo y el costo. En este sentido, este trabajo tuvo como objetivo evaluar la viabilidad técnica del mapeo altimétrico y la construcción de maquetas 3D, mediante el uso de drones, geodesia de precisión e impresoras 3D como una alternativa extremadamente eficaz y de bajo costo para la modelización ambiental. El trabajo tuvo como recorte espacial experimental los límites del terreno del IFRN/Campus Macau. El estudio se llevó a cabo en cinco etapas: I) Revisión bibliográfica; II) Levantamiento geodésico (GNSS); III) Levantamiento aerofotogramétrico; IV) Procesamiento de los datos geodésicos y aerofotogramétricos; y V) Impresión 3D. Se obtuvo un protocolo para la elaboración con alta precisión vertical y horizontal del Modelo Digital de Superficie (MDS), ortomosaico y maqueta 3D (virtual y física) del ambiente mapeado. Respecto a la maqueta 3D, su impresión permitió una comprensión perfecta de la geomorfología del ambiente mapeado y de las estructuras físicas existentes. La técnica aplicada puede ser útil en diversas áreas como, por ejemplo, potenciar la etapa de planificación en la construcción civil, arquitectura y estudios ambientales. También se convierte en una gran aliada en futuros estudios geomorfológicos y de cartografía táctil.

PALABRAS CLAVE: geoprocesamiento; aeronave remotamente pilotada; mapeo ambiental; modelo digital de elevación; impresión 3D.

1. INTRODUCTION

The mapping process provides essential data for a variety of activities, enabling the identification and analysis of phenomena occurring on the surface of the environment (Lakshmi; Yarrakula, 2018; Coelho *et al*., 2018; Guth *et al*., 2021). The cartographic products of mapping are essential for the organization and understanding of activities such as planning, land use, infrastructure, urban and rural registry, and environmental management, among others (Souza, 2015; Araújo *et al*., 2018; Aguiar *et al*., 2018; Araújo *et al*., 2019). The most common form of mapping is through conventional topography, which involves angular and linear measurements on the earth's surface for calculating volumes, areas, and coordinates. However, it is imperative to possess a proficient comprehension of instrumentation, calculation methods, and measurement techniques to obtain accurate results (Kahmen; Faíg, 1988). The traditional method of topographic mapping requires more physical effort and time compared to new trends, such as the object-oriented method. This is due to the installation of equipment, changes of stations, and the longer collection time for each point (Santos *et al*., 2014; Fortunato, 2018).

Recent years have witnessed the advancement of geotechnologies, the constant use of Remotely Piloted Aircraft (RPA) has been increasing, offering both technical and economic advantages over traditional surveys methods (Ferreira *et al*., 2013). The term RPA refers to any unmanned aerial vehicle that is piloted from a remote pilot station for purposes other than recreation (ANAC, 2017). The term "Drone" comes from the English word to "male bee", due to the buzzing sound emitted by the equipment in operation, and it is a synonym for RPA commonly known in the media (DECEA, 2023).

The main products provided by aerial mapping with drones are Digital Surface Models (DSMs), Digital Terrain Models (DTMs), and orthomosaics. The primary advantages of Digital Elevation Models (DEMs) generated by drones include superior spatial resolution, more detailed 3D modeling, and a better comprehension of landscape relationships (Isioye; Jobin, 2012). The current ease of performing autonomous flights, coupled with the affordable cost of coverage and photogrammetric systems, renders drones viable as technology applied to topographic mapping (Soares, 2018).

In certain other applications such as architectural surveys of buildings and monuments, remote measurement technologies (without contact), such as laser scanning, facilitate the generation of digital information about the object and enable not only documentation but also the creation of 3D models (Cintra; Gonçales, 2019). Nevertheless, the laser scanner is still a high-cost tool, which makes its dissemination difficult. Furthermore, drones can be a tool to assist in the continuous monitoring of construction sites and provide high-quality data for future technical engineering interventions in the mapped areas.

The growing demand for innovative and effective methods in the field of environmental modeling highlights the need to explore new technologies that can be integrated into educational processes (Koelemeijer; Winterbourne, 2021). The use of drones, precision geodesy, and 3D printers not only facilitates the acquisition of detailed topographic data but also offers significant opportunities for teaching and learning. The ability to create accurate and tangible three-dimensional models of studied terrains can enrich the curriculum of technical and higher education courses, providing students with a deeper and more practical understanding of geographical and environmental concepts. Additionally, the inclusion of 3D printing and virtual reality technologies can aid inclusive education, especially for visually impaired students, by allowing tactile interaction with physical models (Gual-Ortí; Puyuelo-Cazorla; Lloveras-Macia, 2013).

Given the above, the aim of this work is to assess the technical feasibility of altimetric mapping and 3D model construction utilizing drones, precision geodesy, and 3D printing as a highly efficient and cost-effective alternative for environmental modeling.

2. MODELED EXPERIMENTAL AREA

The research focused spatially on the boundaries of the terrain of the Federal Institute of Education, Science, and Technology of Rio Grande do Norte (IFRN), Macau Campus. The IFRN/Macau Campus is in the Macau Municipality, Rio Grande do Norte State, Brazil (Figure 1). It is specifically situated in the Potiguar Central Mesoregion (administrative region) and in the Costa Branca Pole (touristic pole), belonging to the northern coast of Rio Grande do Norte. The Macau Municipality is within the Caatinga biome and has approximately 27,369 in habitants (IBGE, 2022). It has a territory of 788 km2 and is located 180 km from the capital of the RN state, Natal. The municipality borders the north with the South Atlantic Ocean, the south with the municipalities of Pendências and Pedro Avelino, the east with the municipalities of Guamaré and Pedro Avelino, and the west with the municipalities of Porto do Mangue and Pendências.

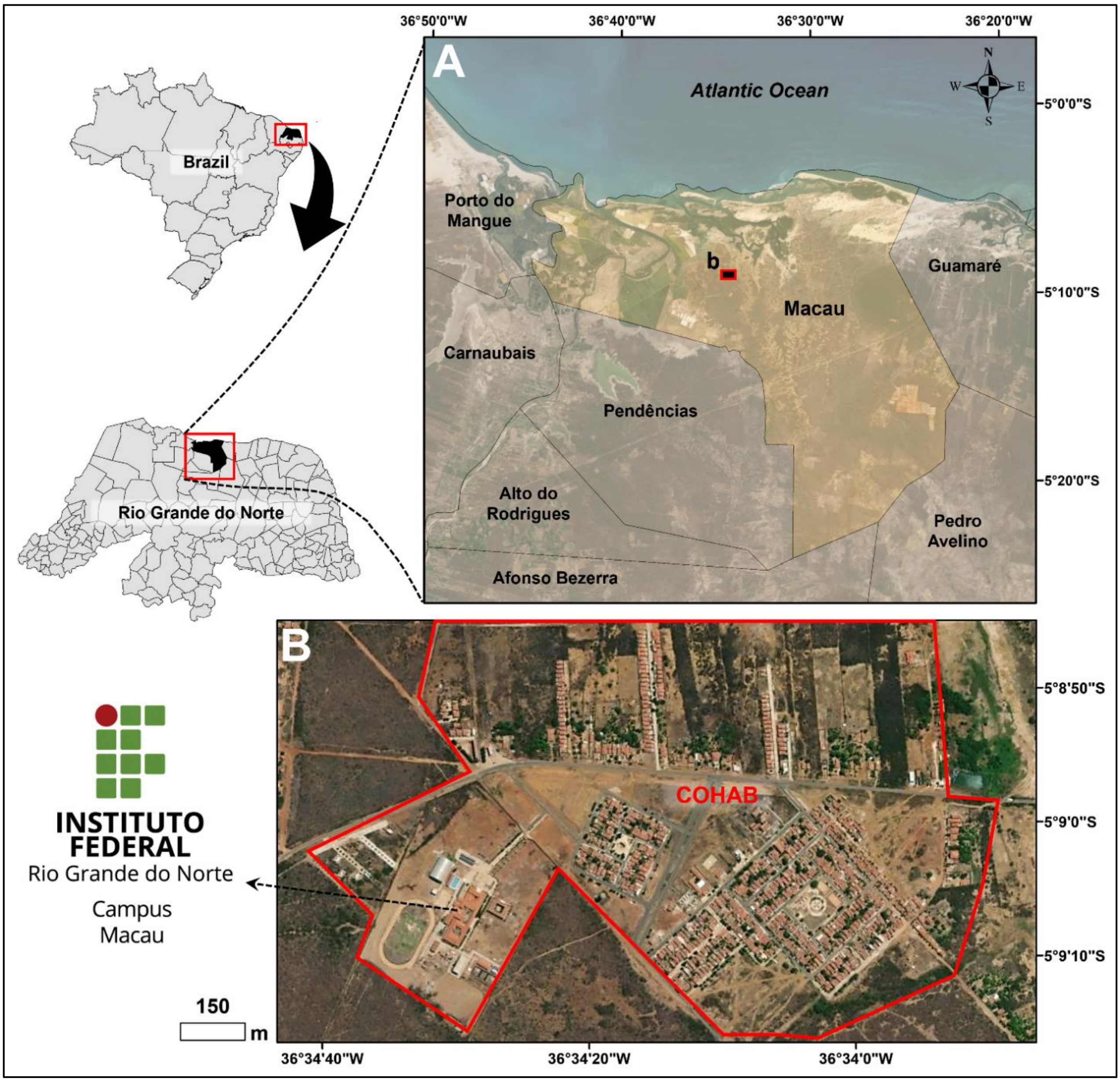
This geographical region is one of the largest salt producers in Brazil and possesses significant natural and competitive advantages for the cultivation of farmed shrimp (Diniz; Vasconcelos, 2016; Diniz; Vasconcelos, 2017; Pontarolo *et al*., 2020). Its saline potential is closely related to the climatic aspect of the region. Macau is characterized by a tropical or equatorial climate and falls under the subdomain of semi-arid climate (Diniz; Pereira, 2015). The region in focus stands out as the driest stretch of the entire Brazilian coast, with an average precipitation of 537.6 mm/year. Daily temperatures range from 26 to 30°C (with an average temperature of 26.8°C), and the average relative humidity is 70% (Diniz; Pereira, 2015; BARBOSA *et al*., 2018; ARAÚJO *et al*., 2021).

Located on a 290,770 m^2 terrain, the IFRN/Macau Campus is part of the second phase of the Expansion Plan of the Federal Network of Professional and Technological Education of the Ministry of Education, initiated in 2007 (IFRN, 2012). The campus offers Integrated Technical courses in Fisheries Resources, Chemistry, and Informatics, as well as undergraduate courses in Biology and Chemical Process Technology. It also offers a specialization in Teaching Natural Sciences and

Mathematics. Currently, the IFRN/Macau Campus has approximately 1200 enrolled students and has a qualified faculty, mostly consisting of master's and doctoral degree holders, with experience in research published in national/international journals.

The campus of IFRN/Macau is equipped with a comprehensive infrastructure to facilitate the teaching-research-extension triad. This includes 13 air-conditioned classrooms with multimedia projectors, an auditorium for 141 people, a sports complex, a library, and administrative offices. Additionally, it has several thematic laboratories to support educational and research activities.

Figure 1: **Location map: (A) Macau Municipality; and (B) COHAB Neighborhood and IFRN/Macau Campus**



Source: Developed by the authors, 2024.

3. METHODOLOGY

In the course of this investigation, an interdisciplinary approach was employed to examine the technical feasibility of altimetric mapping and 3D model construction utilizing drones, precision geodesy, and 3D printers. This section describes the procedures adopted and the equipment used. The integration of these emerging technologies was carefully planned to ensure the precise acquisition of topographic data and efficient construction of three-dimensional models, aiming to achieve reliable and comparable results with traditional methods of environmental modeling.

Field activities adhered to all protocols and general recommendations outlined in the Contingency Plan of the Federal Institute of Education, Science, and Technology of Rio Grande do Norte for Coping with the New Coronavirus. The work was divided into five stages:

3.1 Literature review

Firstly, a thorough research and reading of all available and considered important literature on the focused topic was conducted, mainly in scientific articles, theses and dissertations, books, and technical reports. Studies on the use of drones in environmental mapping, construction of models and 3D printing, topographic surveying, and precision geodesy were fundamental terms in the research.

3.2 Geodetic survey (GNSS)

Before conducting the flights, ground control points (GCPs) were established, which were surveyed using a RTK GNSS (Global Navigation Satellite System) receiver (L1/L2), to allow for the correction of the modeling of Remotely Piloted Aircraft (RPA) data to the desired reference plane (Araújo *et al.*, 2018) (Figure 2). A reference base was installed using the GNSS receiver, collecting data at 1-second intervals.

3.3 Aerophotogrammetric survey

During this stage, the planning process took into account factors such as sunny days to mitigate shading (with a sun elevation above 30°) and gentle winds below 35 km/h. Standardized flights were executed (at 80 meters above ground level with the RPA), sufficient for generating orthophoto mosaics with approximately 3.4 cm spatial resolution. Flight plans were plotted and executed using an iPhone XR smartphone with iOS 16 operating system, in DroneDeploy software version 4.35. During the flight plan elaboration, parameters such as altitude (80 meters above ground level with the RPA), lateral (75%) and longitudinal (75%) photo overlap, camera position at 90° nadir, direction (-135°), and flight speed (9 m/s) were established. The DJI Phantom 3 Professional RPA was used during the flights. The onboard sensor had a resolution of 12.4 M and a 94° 20 mm field of view (FOV).

During planning, it was estimated that the flight time would be approximately 15 minutes, covering an area of 17 hectares, and requiring only one battery.

Figure 2: **A) Ground control point marking; B) GCP acquisition with GNSS receiver**

Source: Developed by the authors, 2024.

3.4 Processing of geodetic and aerophotogrammetric data

The GNSS data of the reference base were post-processed using the Precise Point Positioning service of IBGE (PPP-IBGE) (Araújo *et al.*, 2019). The IBGE-PPP (Precise Point Positioning) is a free online service for post-processing GNSS (Global Navigation Satellite System) data, which utilizes the CSRS-PPP (GPS Precise Point Positioning) program developed by NRCan (Geodetic Survey Division of Natural Resources of Canada). It allows users with GPS and/or GLONASS receivers to obtain coordinates referenced to SIRGAS2000 (Geocentric Reference System for the Americas) and ITRF (International Terrestrial Reference Frame) through precise processing. The IBGE-PPP processes GNSS data (GPS and GLONASS) collected by receivers with one or two frequencies in static or kinematic mode.

For the processing of the photogrammetric data, the Agisoft Metashape Professional software was used, allowing for the insertion of images obtained with the RPA. The processing followed an available semi-automatic routine, where specific interventions were made for parameter insertion, noise and distortion elimination, and insertion of the geodetic values of the GCPs. With the photogrammetric processing, the 3D model (virtual) of the mapped environment, the Digital Surface Model (DSM), and the orthophoto mosaic adjusted to the Brazilian Geodetic System (SGB) were obtained, since the model was corrected with the GCPs post-processed by the PPP-IBGE.

The quality parameters of the products were obtained from the report of products and processing of the Agisoft Metashape Professional software.

3.5 3D printing

The Digital Surface Model (DSM) was imported into the QGIS software, where it was converted into a 3D file (.stl) using the "DEMto3D" plugin. Next, the 3D file was sliced (in scale 1:1750) using the free software Ultimaker Cura. Slicing involves converting the 3D model into instructions for the 3D printer. The parameters used in slicing are mentioned in Table 1.

Table 1: **Print setting mains in software Ultimaker Cura**

3D print settings main	
Layer Heigth	0.12 mm
Initial Layer Heigth	0.12 mm
Line Width	0.4 mm
Wall Thickness	1.2 mm
Printing Temperature	200 °C
Build Plate Temperature	60 °C
Print Speed	50 mm/s
Retraction Distance	5.0 mm
Retraction Speed	45 mm/s
Build Plate Adhesion Type	Brim
Brim Width	8.0 mm
Brim Line Count	20
Brim Only on Outside	Yes
Material	PLA
Nozzle Size	0.4 mm
Material Color	White
Estimated Material	84g - 28.09 m
Estimated Printing Time	20 hours 10 minutes

Source: Developed by the authors, 2024.

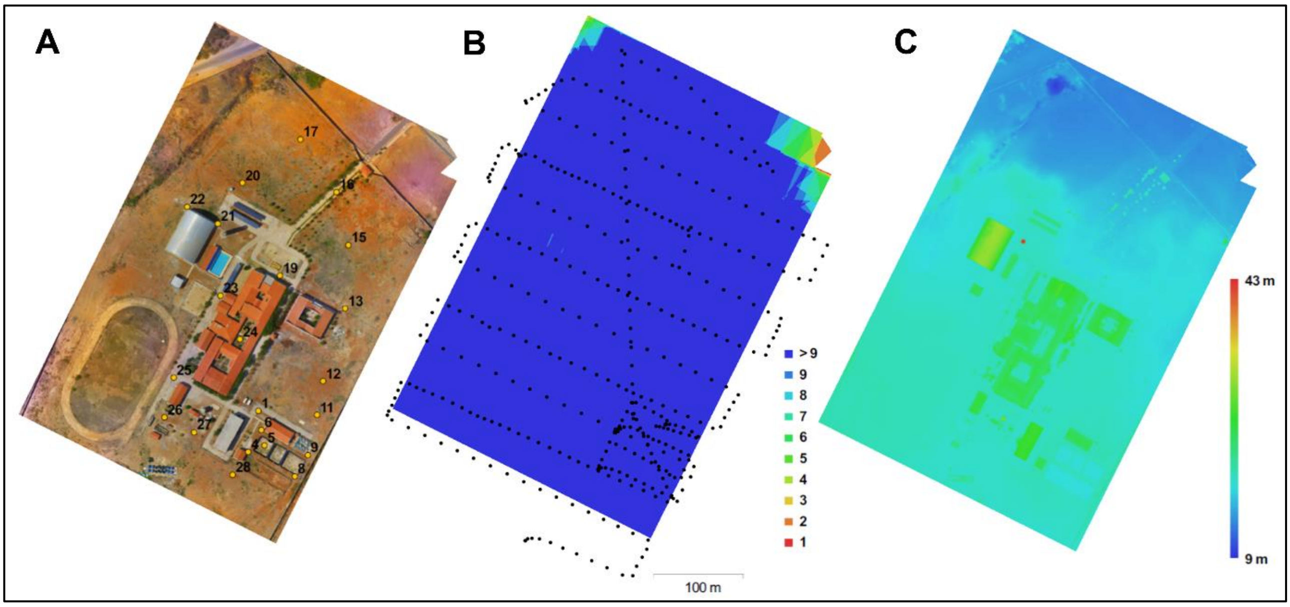
Finally, the 3D Model (3D Maquette) was printed using a Creality Ender-3 3D printer (printing stage through FDM technology).

4. RESULTS AND DISCUSSIONS

The results obtained from the application of the proposed methodology are presented and discussed in this section, providing valuable insights into the effectiveness and precision of altimetric mapping techniques and 3D model construction using drones, precision geodesy, and 3D printers.

In total, 22 ground control points were marked, tracked, and post-processed (Figure 3A). The average altimetric error at these points was 1 cm, which conforms to the standards established by the literature (Santos; Amaro, 2011; Santos; Amaro; Souto, 2011; Santos; Amaro; Santos, 2014; Santos; Amaro; Santos, 2015). Post-processing becomes an essential step, since the use of GNSS provides quick information about positioning (referred to as geometric altitude). However, to accurately determine altitude, it is necessary to use a theoretical-mathematical reference, such as the reference ellipsoid. In mapping and engineering works requiring high precision, it is necessary to have a thorough understanding of the geoidal surface, which is related to the Earth gravity field and the unchanged sea surface. This allows defining a geoidal undulation, thereby enabling the designation of an orthometric altitude with physical significance (Blitzkow *et al.*, 2016).

Figure 3: **(A) GCP locations; (B) Camera locations and image overlap; (C) Reconstructed digital elevation model**



Source: Developed by the authors, 2024.

With aerial surveying, a total of 400 photographs were obtained, encompassing a remarkable degree of image overlap across the entire study area, with a predominant presence of more than nine overlapping images (Figure 3B). After incorporating the corrected control points into the photogrammetric processing, a total error of 0.06 cm was obtained (Table 2).

The use of RPAS (Remotely Piloted Aircraft Systems) or UAVs (Unmanned Aerial Vehicles) is becoming increasingly common for mapping the Earth's surface, both in the civilian and military spheres. With current technologies, it is possible to achieve resolutions of a few centimeters with accuracy equal to or even better than conventional mapping methods (Ferreira *et al*., 2013).

Table 2: **The error derived from the model after calibration with GCPs**

GCP	XY Error (m)	Z Error (m)	Erro (m)	Projections	Erro (pix)
1	0.018	-0.014	0.023	49	0.750
11	0.014	0.008	0.016	41	0.665
12	0.040	0.001	0.040	25	0.517
13	0.032	-0.034	0.047	24	0.658
15	0.021	0.003	0.021	23	0.815
16	0.030	0.001	0.030	25	0.454
17	0.019	-0.006	0.020	25	0.307
19	0.075	0.064	0.098	32	0.835
20	0.065	-0.001	0.065	32	0.402
21	0.135	0.038	0.141	24	0.428
22	0.060	-0.043	0.074	27	0.346
23	0.057	0.010	0.058	23	0.432
24	0.031	0.004	0.031	28	0.367
25	0.026	-0.030	0.040	17	0.365
26	0.028	0.005	0.028	22	0.435
27	0.055	0.005	0.056	25	0.550
28	0.017	0.063	0.065	41	1.037
4	0.056	0.010	0.056	65	1.478
5	0.081	-0.066	0.104	74	0.809
6	0.019	-0.024	0.030	60	0.815
8	0.031	0.017	0.035	54	0.557
9	0.020	-0.007	0.021	53	0.545
Total	**0.051**	**0.029**	**0.059**		**0.755**

Source: Developed by the authors, 2024.

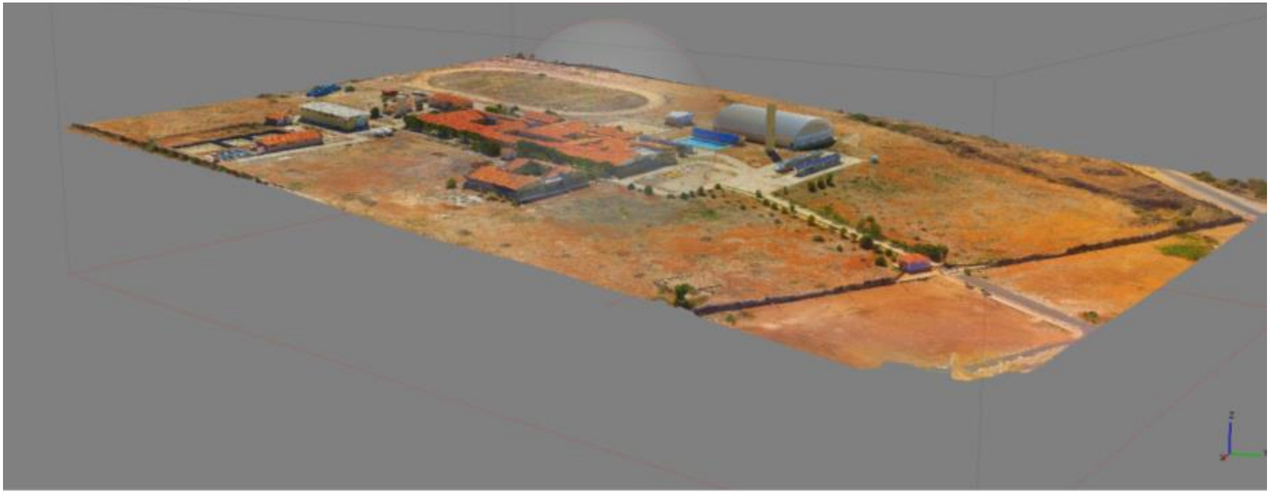
By utilizing RPA, it is achievable to reduce the effort required for topographic surveying and leverage novel geotechnology to obtain accurate digital elevation models of extensive areas, containing a greater quantity of information and in previously inaccessible locations. Although GNSS

(Global Navigation Satellite System) remains the most modern and cost-effective geotechnology for obtaining topographic data of the Earth's surface, when combined with photogrammetry and RPA usage, it becomes a complementary tool to merge remote sensing techniques with precision geodesy, allowing for an integrated and more efficient approach (Mancini *et al*., 2013; Casella *et al*., 2014), although it is always necessary to validate created models to ascertain their accuracy in relation to control points obtained with geodetic GPS on the ground.

The Digital Surface Model (DSM) of the mapped area had an altimetric range from 9 to 43 meters and had a final resolution of 12.8 cm/pixel (Figure 3C). The campus water tank is the highest point in the structure, reaching an orthometric altitude of 43 meters. The Digital Surface Model (DSM) highlights that the IFRN/Macau Campus is on a terrain with a lower portion to the north of the study area, while the higher sectors are located to the south.

Finally, it proved feasible to visualize all the structures of the IFRN/Macau Campus in a virtual reality setting (Figure 4), which would not have been possible through the traditional method (topography with theodolite), besides requiring more time and effort from professionals in the field. Additionally, the materialization of the 3D model in 3D printing proved to be an extremely effective tool, enhancing the understanding of the terrain, and empowering the planning stage of future civil construction interventions (Figure 5).

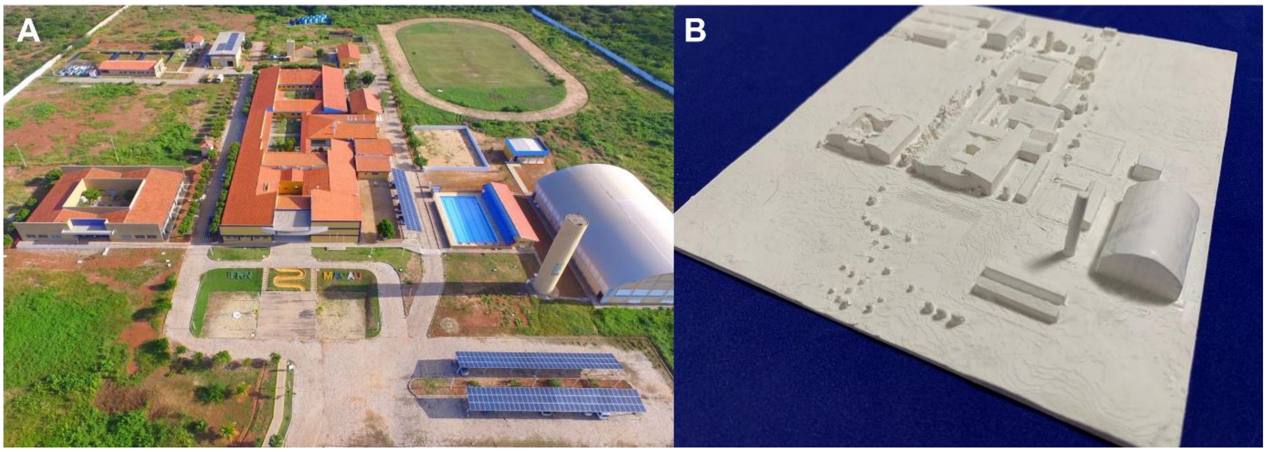
Figure 4: 3D model of the IFRN/Campus Macau in a virtual environment



Source: Developed by the authors, 2024.

The printed three-dimensional model allowed for a clear visualization of the main topographic and structural features of the campus, including buildings, green areas, and terrain elevations. This accurate representation of the physical space not only facilitates the planning and management of infrastructures but also serves as a valuable educational tool.

Figure 5: IFRN/Macau Campus: (A) Real environment; (B) 3D printing made (in scale 1:1750) in dimensions: 14 x 17 cm

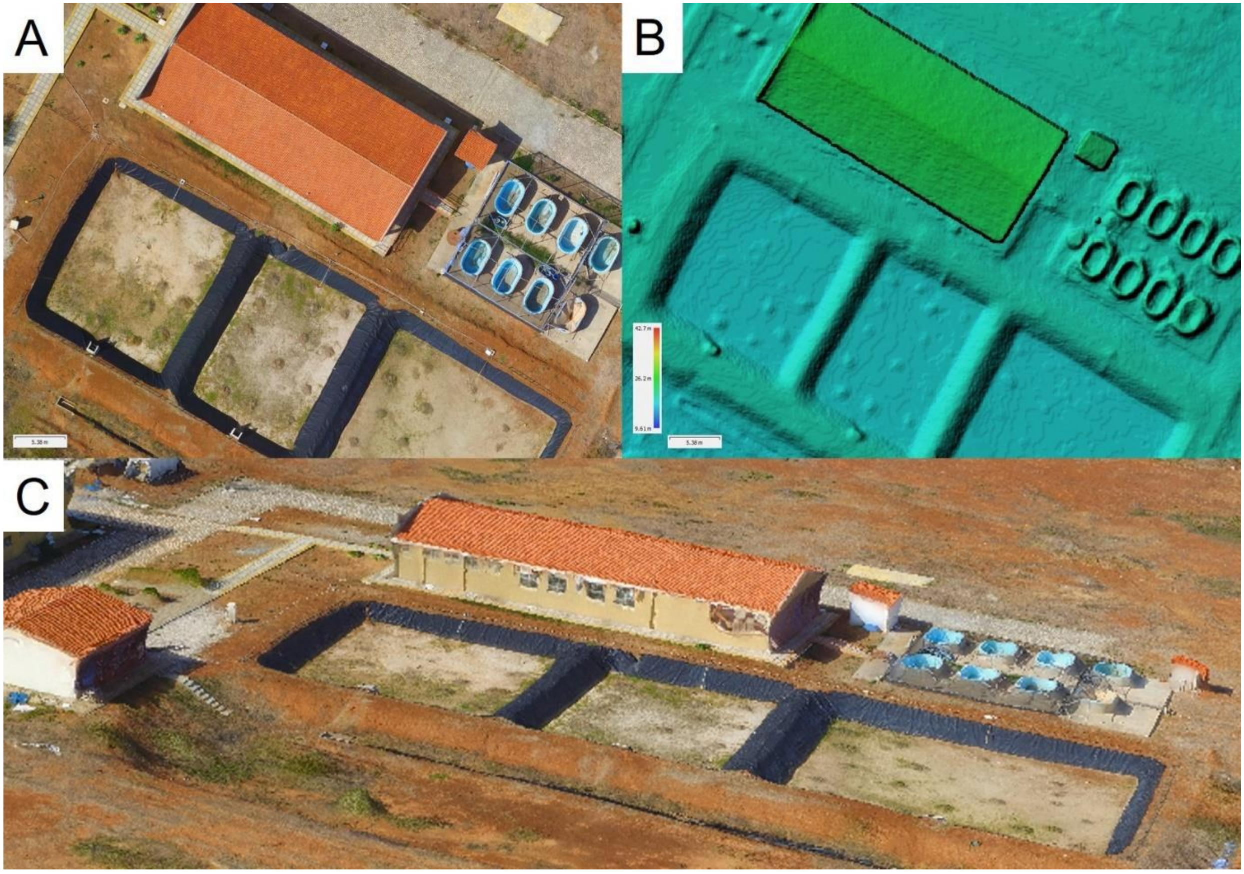


Source: Developed by the authors, 2024.

The integration of products resulted in a better comprehension of the terrain, as well as the structuring potential of the entire focused campus, especially in the aquaculture productive unit of the Management Directorate of the School Industrial Unit of the Macau Campus (DIGUIE/MC) (Figure 6 and Figure 7). DIGUIE/MC is a sector of great importance for the Fisheries Resources Technical Course at IFRN/Macau Campus. In this structural complex, activities related to the management of aquatic organisms, feeding, fishing, biometrics, water exchange, and equipment and pond cleaning are carried out. The highlighted ponds are not currently being used precisely due to a construction waterproofing and topographic error. The analysis of the products provided us with a clear understanding, wherein it is worth noting that, in conventional inspections, analyses are more time-consuming, and the cost ends up being higher due to the time involved. The accuracy level of the survey provided practical and satisfactory exactness to the research.

Koelemeijer and Winterbourne (2021) developed a straightforward technique for exhibiting scalar fields on planets such as Earth, Mars, and the Moon through the utilization of 3D printing. The authors developed 3D prints that were primarily focused on education and provided a powerful way to explain the importance of tectonic plates in planet formation. According to Hasiuk and Harding (2016), the primary advantage of 3D printed models is their affordability, durability, and a wide range of customization options. Additionally, 3D printing can enhance access to learning materials for visually impaired students, as they can use touch to explore models of surface and subsurface structures, fossils, minerals, or even 3D phase diagrams. Harding, Hasiuk and Wood (2021) developed 3D printed models to be used to assist beginner students in learning the "language" of contour maps. Students noted the benefit of 3D printed models in orienting themselves on their basic 2D maps, visualizing large-scale structures.

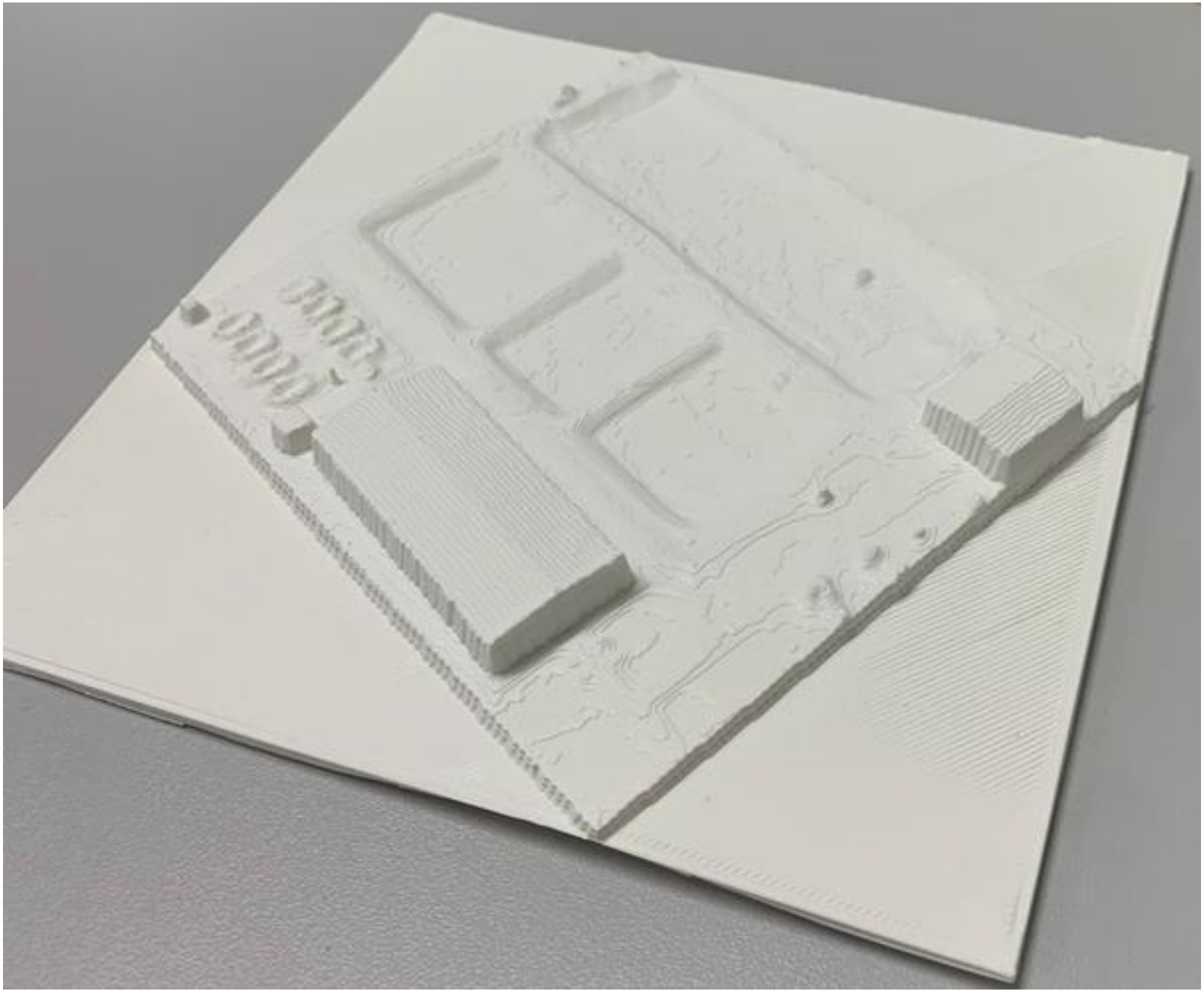
Figure 6: Highlighted detail of the aquaculture productive unit of the Management Directorate of the Industrial School Unit of the Macau Campus (DIGUIE/MC). A: Orthomosaic; B: Digital Surface Model (DSM); C: 3D Model in virtual environment



Source: Developed by the authors, 2024.

To summarize, the findings and discussions presented in this section substantiate the efficacy and technical viability of integrating drones, precision geodesy, and 3D printers for altimetric mapping and the creation of 3D models in environmental modeling. These emerging technologies not only provide a more accessible and cost-efficient approach but also demonstrate comparable or even superior accuracy to traditional methods. However, we emphasize the ongoing importance of research and development in order to further optimize these techniques, ensuring their applicability in a variety of environmental contexts and promoting significant advances in understanding and managing terrestrial ecosystems.

Figure 7: 3D printing of the DIGUIE/MC (in scale 1:1715). Dimensions: 15 x 15 cm



Source: Developed by the authors, 2024.

5. FINAL CONSIDERATIONS

It is essential to have a thorough understanding of terrain and altitude in an area in order to plan and execute various environmental studies. The use of Remotely Piloted Aircraft (RPA) proved to be of utmost importance, providing precise imagery and unlocking endless study opportunities within the depicted spaces. With the rise of Industry 4.0, the utilization of drones and 3D printing has become increasingly prevalent, gaining traction in the market (Beltrão; Pires, 2019; Junqueira, 2020; Alarcão-Júnior; Nuñez, 2024). Our study holds significant importance in disseminating the technical feasibility of employing these new technologies for altimetric mapping, aiming to encourage their adoption in geotechnology. Acquiring proficiency in these geotechnologies is becoming an essential requirement for future employment.

In conclusion, we hope that our pioneering methodology at IFRN will serve as a blueprint for replication across all campuses, facilitating the creation of a comprehensive topographic database for each campus. Such a database could provide a clear snapshot of the engineering sector's activities within the IFRN's administrative body. Moreover, the creation of 3D virtual models for all campuses could serve as a powerful tool for showcasing the Institute's physical structures through a virtual reality platform. Furthermore, the tangible outcome of 3D-printed mappings could be a valuable didactic resource, particularly aiding visually impaired students in comprehending the local terrain through tactile cartography.

ACKNOWLEDGMENT

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