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Daniele La Rosa
Riccardo Privitera *Editors*

Innovation in Urban and Regional Planning

Proceedings of the 11th INPUT Conference—Volume 1

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Preface

The 11th Edition of the International Conference focuses on how to integrate nature-based solutions in urban and regional planning processes and science. Previously planned for September 2020, due to the COVID-19 pandemic the INPUT 2020 Conference will be hosted in 8–10 September 2021 by the University of Catania (Italy).

The overarching theme of INPUT 2021 edition is “Integrating Nature-Based Solutions in Planning Science and Practice”. There is growing evidence that nature-based solutions (NBS) are strategic instruments to restore or improve the functionality of urban ecosystems towards more livable, healthier and resilient cities. Despite their many advantages, NBS are not widely implemented because the evidence of their effectiveness is not yet sufficiently diffused among policy-makers, city-planners and residents and because NBS are often overlooked due to the complexity of their design and lack of normative instruments supporting planning choices. In order to permanently incorporate NBS into planning instruments, more research and international discussion are required to consolidate the fragmented evidence that NBS can significantly improve the overall degree of environmental sustainability of contemporary cities.

INPUT 2020 gathers international scholars in the fields of planning, civil engineering and architecture, ecology and social science, to build and consolidate the knowledge and evidence on NBS and to help an efficient implementation and replication of solutions.

The INPUT 2020 Conference hosts 14 thematic sessions, namely:

- Enhancing the use of nature-based solutions in urban planning
- Modelling to innovate planning solutions for socio-ecological systems
- Input visions: new technologies, data and hybrid models for spatial planning
- Urban metabolism and simulation for decision-making in spatial planning
- Performance-based planning
- Computational planning
- Geodesign for informed collaborative spatial decision-making

- Planning and design of ecosystems services: assessment frameworks, models, mapping and implications
- Green infrastructure for planning healthy urban environments
- The mitigation of peripheralization risk in urban and regional planning
- Strategies and actions for climate change adaptation and mitigation in mediterranean regions
- Analysis and planning of rural landscapes
- Accessibility in urban planning: moving towards innovative approaches
- Maintenance, upgrading and innovation in cultural heritage

This book presents the first collection of 69 contributions submitted to the INPUT 2020 Conference, following the first call for paper launched in Winter 2020. The accepted articles, after a blind-review process, are here organized in 5 topical parts, which group together the 14 thematic sessions of the conference:

- Nature and Ecosystems for Urban Systems
- Models and Technologies for Spatial Planning
- Climate Change and Spatial Planning
- Peripheries, Rural and Cultural Landscapes
- Accessibility in Urban Planning

INPUT 2020 proceedings explores empirical as well as theoretical frameworks for NBS, their attitude to provide ecosystem services, to deal with climate change effects and to support mitigation and adaptation planning strategies. Integration of NBS in planning science and practice is investigated across different contexts and scales, from urban cores to peripheries as well as from rural to cultural landscapes. Above all, this collection presents the state of the art of modelling approaches and innovations employed in urban and spatial planning, with a trans-disciplinary, boundary-less character to face the complexity of contemporary socio-ecological systems and following a practice-oriented approach aimed to problem solving.

INPUT is a group of Italian academic researchers and academics working in different fields related to the exploitation of innovation for urban and regional planning, with particular reference to geo-informatics and socio-ecological aspects of spatial planning. INPUT Conference is held every two years in Italy, with last editions been hosted in Viterbo (2018), Torino (2016), Cagliari (2014) and Potenza (2012).

INPUT 2020 Conference is organized by LAPTA, a research laboratory of Department of Civil Engineering and Architecture of the University of Catania (Italy), working on sustainable urban and landscape planning.

Catania, Italy
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Contents

Use of Remotely Piloted Aircraft to Update Spatial Data in Areas of Social Fragility

Danilo Marques de Magalhães and Ana Clara Mourão Moura

Abstract A considerable amount of the Brazilian population lives in informal settlements, where there is a massive dynamic of territorial transformation. In this sense, the use of Remotely Piloted Aircraft (RPA) has shown an excellent cost-benefit relation for expeditiously collecting spatial data aiming at the identification of territorial objects, which can be an essential resource to assist planning and public management. This study presents a methodology for updating the spatial database collected by airborne LiDAR (Light Detection and Ranging) using an RPA and high precision GNSS (Global Navigation Satellite System) receivers. The study was carried out in an area of social fragility located in Belo Horizonte, Brazil, which presents geomorphological complexity, high density of territorial occupation, unplanned infrastructure, and complex urban morphology. Such associated characteristics are understood as social risk factors, creating difficulties for technical managers and locals. In that municipality, data are collected with airborne LiDAR every seven years for urban management purposes. However, the dynamics of territorial transformation in these places is very intense, generating demand for updating the database. For this purpose, the Digital Surface Model (DSM) generated by RPA was associated with the DSM generated by LiDAR through raster algebra. The results show the buildings' pavement increases and new buildings' construction, indicating to public managers the territorial changes in the analyzed period.

Keywords Remotely piloted aircraft · Urban management · Illegal settlements · Map algebra

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1 Introduction

The monitoring of territorial transformations in Brazil is undoubtedly a significant challenge for urban management, mainly due to many existing irregular settlements. Data from the last demographic census show that 6% of the Brazilian population resides in subnormal agglomerations, identified from the precarious condition of infrastructure in existing households. Most of these households (49.8%) are in the Southeast metropolitan regions and frequently in unsuitable areas for urbanization, such as steep slopes, caves, and banks of watercourses (IBGE 2020).

In the municipality of Belo Horizonte, there are 209 illegal settlements and slums, totaling 714 thousand people living in inadequate conditions of urban and sanitary infrastructure (PBH 2020). In this municipality, the management of territorial transformations is carried out with the support of data captured by LiDAR (Light Detection and Ranging) airborne and aerial photographs taken, performed approximately every seven years. However, territorial change dynamics are quite intense, especially in the peripheral regions, where significant increases in buildings can be seen in less than a month. This situation reinforces the demand for updating the cartographic base in a shorter period, which provides resources for monitoring transformations, dialogue with the local population, the management of necessary infrastructure, and the assessment of regulatory possibilities.

In this sense, Remotely Piloted Aircraft (RPA) has been tested as a resource for collecting data on the neighborhood scale to update the municipality's official database. Therefore, this work presents the tests carried out to integrate the database collected with a low-cost RPA with the database generated from LiDAR, aiming to demonstrate the places where there were more significant territorial transformations, as well as presenting challenges and limits of the proposed method.

Studies show that RPA, when combined with high precision GNSS receivers, can generate MDS with accuracy and morphology similar to models generated by laser profiling performed by LiDAR (Marotta et al. 2015; Oliveira et al. 2017).

2 Study Area

The study area is the Conjunto Paulo VI neighborhood, located in the Northeast portion of Belo Horizonte, Brazil (Fig. 1). It is located on the municipality's borders, and it is considered an illegal settlement, as the inhabitants do not have ownership of the land and organized themselves to occupy the area, which included invasions under a power transmission line from the state's distribution company (CEMIG). Thus, the infrastructural deficiencies are evident, such as sanitary sewage, transportation system, paving, water, and installed energy network, among other situations. The area presents geomorphological complexities, including steep slopes and unstable soils where landslides involving victims have occurred. Some studies show that it is also an area of high vulnerability because of the climate

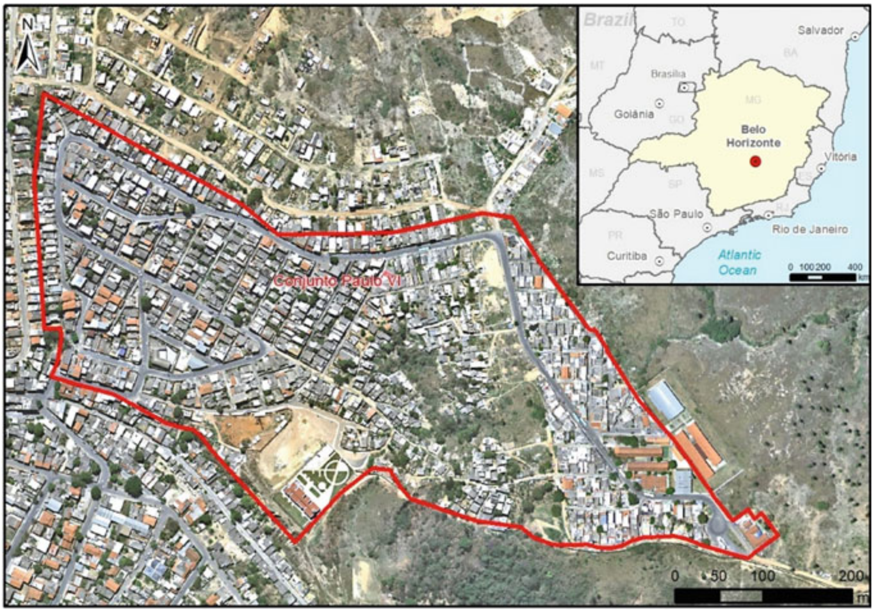

Fig. 1 Location map of study area. *Source* the authors

changes expected for the municipality over a 30-year horizon, and the verticalization in the place may compromise the circulation of winds close to the surface, generating a series of subsequent problems (Way Carbon 2016).

3 Materials and Methods

The study assesses airborne LiDAR data with data generated by RPA to verify the possibility of integrating them and monitoring territorial transformations. The LiDAR data used were generated by the Airborne Laser Scanning system in 2015. They were acquired at a flight height of 2388.1 m, with a field of view of 20° and lateral overlap between the scanning ranges of 36.4%, which resulted in an average density of 6.06 points per square meter.

The comparison and integration of data took place using Digital Surface Models (DSM) in raster format. This data was generated through the point cloud interpolation in 20 cm spatial resolution using the Topo to Raster tool in ArcGIS software.

The RPA used was the multi-engine DJI Phantom 4 Pro. The flight was performed with the Terrain Aware function available in the Map Pilot application. It provides the recognition of the terrain based on an SRTM image, making the RPA remain at a uniform height from the ground. It guarantees the collection of all images with the same GSD (Ground Sample Distance), thus reducing the interference of the terrain variation in the quality of the products generated (Magalhães and Moura 2018; Magalhães and Moura, in press). The flight was carried out at the height of 150 m, in April 2019, at 11:40 a.m., when there is less formation of shadows projected by vegetation and buildings to generate better modeling of the surface (Aber et al. 2010). It took approximately 16 min of flight to cover a total area of 65.36 ha, with a total of 261 images at 4.1 cm of GSD each.

In order to ensure the planimetric and altimetric accuracy of the RPA's products, 9 GCPs (Ground Control Points) were collected in a dispersed way in (Santos et al. 2016; Zanetti et al. 2017). The GCPs were collected with the Topcon dual-frequency receiver model Hiper SR, using the static method (Monico 2000). The base receiver performed the observations for 4 h 30 min and the other points, collected by the rover, for 20 min each. The data generated were also corrected based on the Brazilian Network for Continuous Monitoring (RBMC) using the Topcon Tools software.

For generating the DSM from the photographs collected by the UAV, the Agisoft PhotoScan software was used, which allows the 3D reconstruction of objects through an algorithm that operates on multiple images with different perspectives. Medium accuracy and an aggressive filter were adopted as parameters for the point cloud construction, and the DSM was generated in this same software with spatial resolution, also, of 20 cm.

Both surface models were cut in the study area that consists of the Conjunto Paulo VI neighborhood boundary plus a 50 m buffer to avoid edge effects in the data processing.

Simple map algebra was employed to verify the temporal transformations by subtracting DSM RPA (2019) by DSM LiDAR (2015). The results had some noises due to the greater density of the RPA point cloud than LiDAR and, consequently, the product quality difference. In order to reduce this noise and facilitate data analysis, a 5×5 smoothing filter was applied. This entire procedure was performed using ArcGIS software.

From these data, profile graphics were made to compare the occurred transformations and to interpret the results generated, which are presented below.

4 Results and Discussions

Based on the profile graphs generated on the DSM, values groupings were made to understand the changes and separate the existing data noise.

The first group, with values from −30.1 to −1.5 m, shows the places where the vegetation cover was removed and other objects extinct over the analyzed period. Several irrelevant changes related to the study proposes were observed, such as variation of parked vehicles and a significant volume of noise arising from the difference between the analyzed product's quality. Such factors excluded this class from the analysis.

The values identified between −1.4 and 1 m represented those places that remained unchanged in the analyzed period, basically corresponding to the model's road axes and the buildings without noticeable modifications. It was noticed significant noises in results up to 1 m when located at the building's edges due to the difference in data quality. Therefore, these values were not considered as real changes.

The values from 1 to 3 m represented building changes of up to 1 floor, which could be a new building where there were none or the increase of a new floor in an existing one (Fig. 2). The figure shows that it is impossible to perceive the building's increased volume only using aerial photos. Besides, the steep relief, the densification of buildings in narrow alleys, and the vegetation make the analysis process hard. However, the profile graph shows that both data's terrain is quite similar, which generates reliability in the analysis.

The results with values between 3 and 6 m represent the buildings with an increase of up to two new floors. As these are more significant changes concerning the neighbors, these places had a low amount of noise and, therefore, a robust identification.

The values that show changes from 6 to 9 m represent those buildings with an increase of up to three floors. In general, the results were quite similar to those of the previous class: a higher altimetric increase leading to a smaller amount of noise in the data due to a more evident change and less interference from the surrounding objects. In the study area, few changes were identified at this level; for instance, the construction of a public hospital with three floors stands out (Fig. 3). In some places, it was also possible to see the vegetation increases. However, this data is not reliable since LiDAR technology can capture information also under the canopy of trees, and the differences between these data make the analysis unfeasible.

Alterations were also identified in two buildings in the neighborhood that resulted in values between 9 and 12 m, representing an increase of up to four floors. As in the previous two classes, no significant noises were observed in this class due to the significant variation between the dates analyzed.

With values greater than 12 m, the last class consists of noise from the data and changes observed in the vegetation that is not reliable—as already mentioned—and neither object of this analysis. No significant increments of more than four floors were observed in the neighborhood buildings within the analyzed period.

It is essential to highlight that this analysis required a strong human-machine interaction, which means that it takes a significant time to be done, and it is not friendly to the automation process. Other related methodologies and other spatial analysis filters can be tested to make it feasible.

On the other hand, the results are reliable since both MDS have similar accuracy. And the presented analysis can be done quickly and by simple map algebra, which can help public managers understand the main territorial changes and then guide the field works.

In this sense, the altimetric data observed on both analyzed DSM were consistent since the GNSS receivers were used to improve the drone's data. It can be understood as a reference to the accuracy of the results.

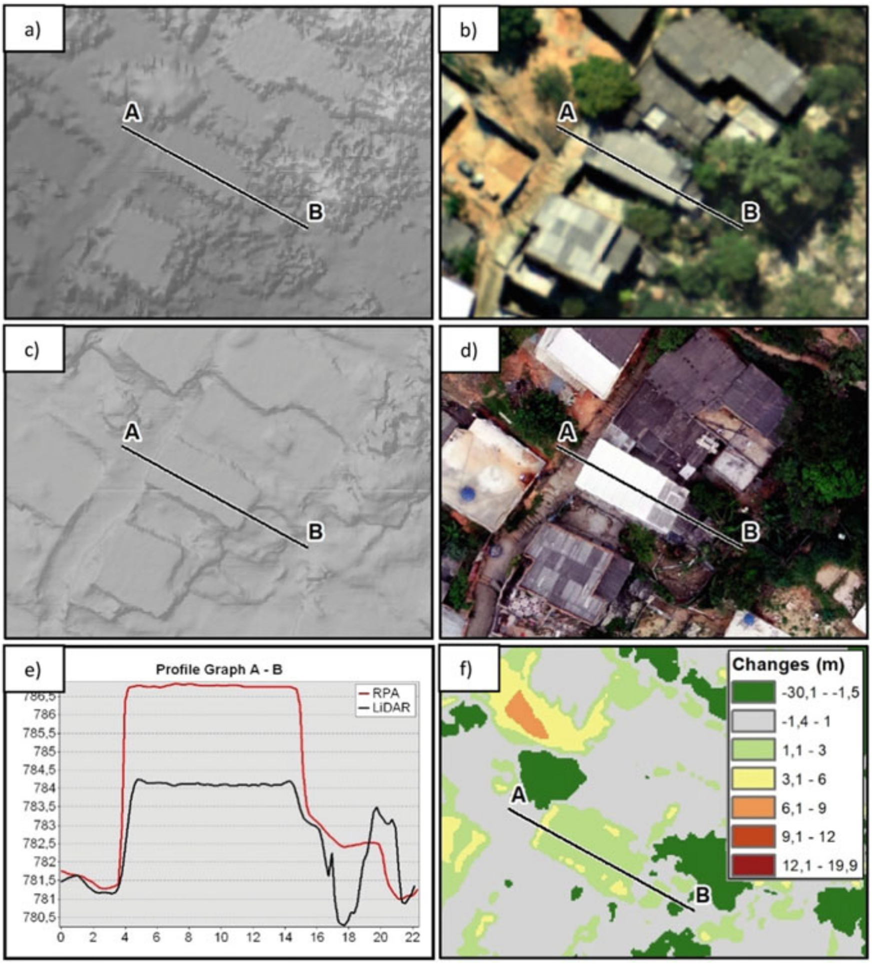

Fig. 2 Changes up to 3 m—Construction of a new floor. **a** DSM LiDAR (2015); **b** Orthomosaic PBH (2015); **c** DSM RPA (2019); **d** Orthomosaic RPA (2019); **e** Profile graph; **f** Result of map algebra (DSM RPA—DSM LiDAR). *Source* the authors

The biggest challenge in this analysis was to filter the noise to understand the information generated. It is caused by the different density of the point clouds used to create the surface models, and the analyst will need to deal with it. In the study presented, it became viable from studying the shapes of the features observed on the orthomosaics and its comparison with the forms observed in the DSMs. Another challenge to face when working with RPA images is the shadows cast by the trees, the buildings, and other objects, making it impossible to generate a precise surface model in these areas. It is a well-known problem concerning drone images, and it is necessary to be aware of the limits of this technology's use.

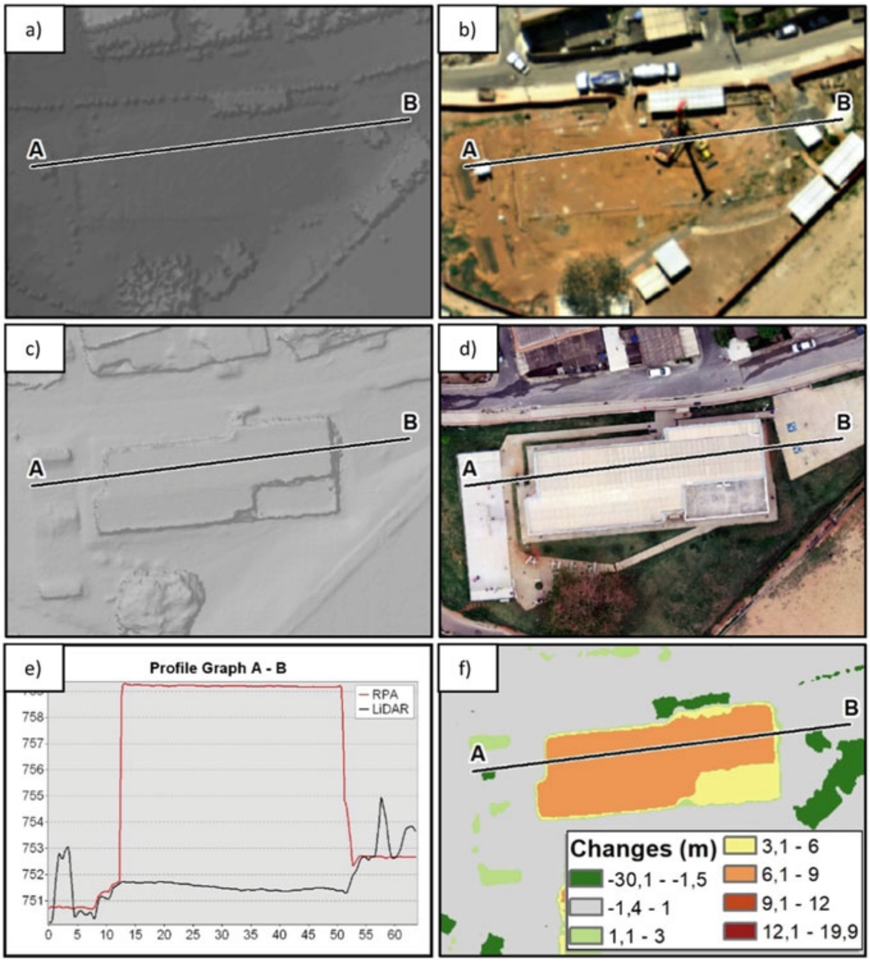

Fig. 3 Changes up to 9 m—Public health center. **a** DSM LiDAR (2015); **b** Orthomosaic PBH (2015); **c** DSM RPA (2019); **d** Orthomosaic RPA (2019); **e** Profile graph; **f** Result of map algebra (DSM RPA—DSM LiDAR). *Source* the authors

5 Conclusions

This work allowed us to conclude that the RPA can be an important instrument to monitor territorial transformations in the presented context, as it is considered feasible to associate the data collected with the LiDAR database. The study reinforces that using GCP to improve the RPA products is possible to achieve an accuracy similar to the LiDAR data. In this sense, there are gains in cost reduction and agility in collecting and updating data, enabling neighborhood scale and on-demand works.

Significant noises were observed among the data that must be treated carefully, avoiding erroneous analyzes.

It is essential to emphasize that this work does not eliminate the necessity for on-site visits to validate the transformations for cadaster purposes. However, it can guide managers to plan these actions in a more agile and assertive way.

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