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Evaluation of urban permeability rates intra-lot assisted by RPA images

Avaliação das taxas de permeabilidade intra-lote auxiliada por imagens de RPA

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Abstract

The urbanization process of the municipality of Irati-PR occurred in an intense and accelerated way, being unavoidable the ground waterproofing through buildings, pavements of the streets, walks and patios. Due to this process, several factors of the natural environment are modified, for example, the soil reduces the infiltration capacity, implying an increase in the surface runoff rate and its velocity, contributing significantly to floods occurrence. Therefore, the work objective is to evaluate the urban environmental quality in a neighborhood of the Irati city, Paraná State, using very high spatial resolution images. The vectorization technique on screen allows mapping the permeable areas within the lots and estimating in square kilometers their occupation. With the percentage of permeability, the comparison with the minimum permeability rate required by municipal legislation can be carried out. The study result showed that of the 82 lots analyzed, 47.56% are irregular with the legislation. Through the results obtained, the conditions of each court were evaluated concerning the confrontation with the current legislation.

Keywords: RPA-Remotely piloted aircraft. Urban planning. Land occupation. Permeable area.

Resumo

O processo de urbanização do município de Irati-PR ocorreu de forma intensa e acelerada, sendo inevitável a impermeabilização do solo por meio de edificações, calçamentos das ruas, passeios e pátios. Devido a esse processo, diversos fatores do meio natural são modificados, por exemplo, o solo, reduz a capacidade de infiltração, implicando no aumento da taxa de escoamento superficial e de sua velocidade, contribuindo significativamente para ocorrência de inundações. Diante disso, o objetivo do trabalho foi avaliar a verificar a efetividade do uso de imagens de ARP para análise da taxa de permeabilidade em um bairro da cidade de Irati, Paraná, utilizando imagens de altíssima resolução espacial. A técnica de vetorização sobre tela permitiu mapear as áreas permeáveis dentro dos lotes e estimar em quilômetros quadrados sua ocupação. Dispondo do percentual de permeabilidade do solo pode ser realizada a confrontação com a taxa de permeabilidade mínima exigida na legislação municipal. O resultado do estudo demonstrou que dos 82 lotes analisados 47,56% estão irregulares conforme a legislação. Por meio de resultados obtidos, foram avaliadas as condições de cada uma das quadras em relação à confrontação com a legislação vigente.

Palavras-chave: ARP-Aeronave remotamente pilotada. Planejamento urbano. Ocupação do solo. Área permeável.

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Introduction

The urbanization process in Brazil occurred in an intense and accelerated way. According to IBGE data, the urbanization rate in 1950 was 36.16%, in 2010 it was 84.36%. The urban development of the city of Irati occurred in a similar way, in 1950 31.37% lived in urban areas, in 2010 about 79.94% (IBGE, 2019).

According to Tucci (2008), this increase in the population concentration in a reduced space caused changes and a great dispute over the same natural resources, culminating in the destruction of part of the natural biodiversity.

Formal and often informal occupations in urban areas have progressively undergone a process of consolidation and densification, with grounding processes of lowland areas, canalization of natural drainage courses of the basin, besides waterproofing resulting from urbanization. Thus, the settlements promoted impacts on the natural dynamics of runoff and water infiltration and, consequently, on the natural drainage process. With urban development, it is inevitable the soil impermeability through buildings, street pavements, sidewalks, and patios.

Due to this process, several factors of the natural environment are modified, reducing the infiltration capacity, implying an increase in the surface runoff rate and its speed, contributing significantly to the occurrence of floods. In the face of these adverse impacts, there is a concern to maintain the environmental characteristics, essential for the continuity of ecosystems, and the use and the cover of the soil in an orderly manner is a measure to mitigate the effects, with the beneficial results applied to well-being social (CASSILHA; CASSILHA, 2009).

Studies of the urban environment are important and increasingly indispensable, besides representing the main environment of the contemporary man, are constantly changing. The evaluations of urban environmental quality can be used as a resource in making planning and management decisions that seek to reduce or even avoid the impacts caused by anthropic actions on the environment (ESTÊVEZ; NUCCI, 2015). Urban planning has the role of recognizing, locating trends or propensities, as well as establishing the rules, restrictions, and limitations of land occupation that must be observed to maintain and increase the quality of life for its residents (REZENDE; CASTOR, 2006).

Although Brazil has strict environmental legislation, there is a lack of inspection, often due to the large size of the areas and the restrictions on information about them, in addition to the cost of time and qualified employees to execute the work (NASCIMENTO *et al*., 2005).

In these conditions, Remote Sensing (RS) and Geographic Information System (GIS) techniques assist in the delimitation of extensive areas of potential preservation, being able to efficiently express concepts of territorial expression, such as the potential units of the land use, the zones of influence of a given parameter, critical areas, dynamic power centers, and permanent preservation areas (SILVA, 2001).

In recent decades, the development of orbital and aerial sensor technology has provided urban and environmental managers with an increasingly better tool for technical and scientific studies. According to the Irati City Master Plan (IRATI, 2016a), the city's urbanization process started in the town central area and expanded to other regions, dramatically increasing the occupied urban perimeter. The estimated population for 2018 was 60,357 inhabitants, with an urbanization rate of approximately 80% and a population density of 56 inhabitants/km^2 (IPARDES, 2019). The urban perimeter of Irati consists of 5.189,47 hectares distributed in 20 neighborhoods, totaling 15 thousand lots and 440 blocks (MALHEIROS *et al*., 2019). The environment is constantly changed to meet human needs. However, anthropic actions do not measure interests in order to maintain environmental balance.

For Tucci, Porto and Barros (1995) this process threatens the functioning of the hydrological cycle, because it changes the vegetation cover, thus, the portion of water that previously infiltrated the exposed soil or with vegetation, remains on the surface, increasing the amount and speed of runoff. The problem starts in the rural environment and intensifies in urban area.

Tucci (2000) warns that if the waterproofing of 7% of the area of the lots occurs will already result in the doubling of the surface runoff and that in more extreme cases, with the waterproofing of 80% of the lot generates a volume of runoff eight times greater. Tucci and Marques (2000) comment that, in addition, there will be an increase in maximum flow rates due to the increment in the surface runoff capacity through the conduit and rain channels, reducing the travel time and anticipating their peaks. The same authors also claim that another impact generated by impermeable surfaces is the increase of the ambient temperature. The ability of surfaces to absorb part of the solar energy can cause a phenomenon known as heat islands, which usually occurs in the central areas of cities, where there is a predominance of concrete and asphalt.

Article 30 of the 1988 Federal Constitution defines that land use is municipal and the municipality is responsible for: promoting, as appropriate, proper territorial ordering, through planning and control of the use, parceling and occupation of urban land (BRAZIL, 1988). The land use has different characteristics in urban and rural areas. The activity of land parceling in an urban area or urban expansion is regulated by federal laws nº 6,766/79 and nº 9,785/99. According to these laws, land parceling may occur in the form of dismemberment or allotment. As specified by Law nº 6,766/79 if there is the need to adapt to regional and local peculiarities, states and municipalities may establish complementary regulations (BRAZIL, 1979). Law nº 6,766/79 had changed regarding areas intended for the circulation system, institutional areas, as well as free spaces for green areas, current standing the Law nº 9,785/99 (BRAZIL, 1999).

Articles 182 and 183 of the 1988 Federal Constitution broach urban development policy and define basic guidelines for ordering the full development of the city's social functions, with a view to the well-being of its inhabitants. To this end, since its promulgation, municipalities with more than 20 thousand inhabitants are obliged to prepare and publish the Master Plan (BRAZIL, 1988).

In order to assist the urban policy of the municipalities and establish guidelines for urban planning and development, in 2001 Law nº 10,257, called the City Statute, was published, this law is an instrument of citizenship, since it guides the democratic management of cities and establishes norms of public order and social interest that regulate the use of the urban property for the benefit of the collective good, security and well-being of citizens, as well as environmental balance (BRAZIL, 2001).

In the city of Irati-PR, the planning guidelines are guided by Municipal Law nº 4,228/2016 that institutes the City Master Plan (IRATI, 2016a) and its complementary laws, such as Municipal Law nº 4,231/2016 that regulates the use and occupation of urban and rural land (IRATI, 2016b) and Municipal Law nº 4,234/2016 which provides for the parceling of land for urban purposes in the municipality (IRATI, 2016c). Thinking about the environmental quality and urban adequacy of natural resources, Law nº 4,231/2016 includes definitions of land occupation fees for landowners, in which the permeability rate is expressed in percentage values, proportional to the plot area being the relationship between the permeable area and the lot area. The permeability rate varies from 0 to 50% depending on the zone in which the lot is inserted (IRATI, 2016b).

In allotments, horizontal condominiums, and divisions with more than ten units, is required that the rainwater drainage network considering the capacity of the existing drainage system, according to a project approved by the Municipal Secretariat of Architecture, Engineering, and Urbanism (IRATI, 2016c).

According to Art. 56 of the Municipal Law nº 4,235/2016 it is forbidden to waterproof the lot more than the quota allowed by the Law of Use and Occupation of the soil, its non-compliance will imply sanctions applied by the construction inspector of the Municipal Secretariat of Architecture, Engineering and Urbanism (IRATI, 2016d). Currently, especially in the organization of the urban area, the use of geotechnologies has become important for the establishment of integrated plans for the conservation of water and soil (FLAUZINO; SILVA; NISHIYAMA, 2010), having as tools and auxiliary data sources the Geographic Information Systems (GIS), Remote Sensing (SR), Digital Cartography, Satellite Navigation Systems (CORREA; FERNANDES; PAINI, 2010).

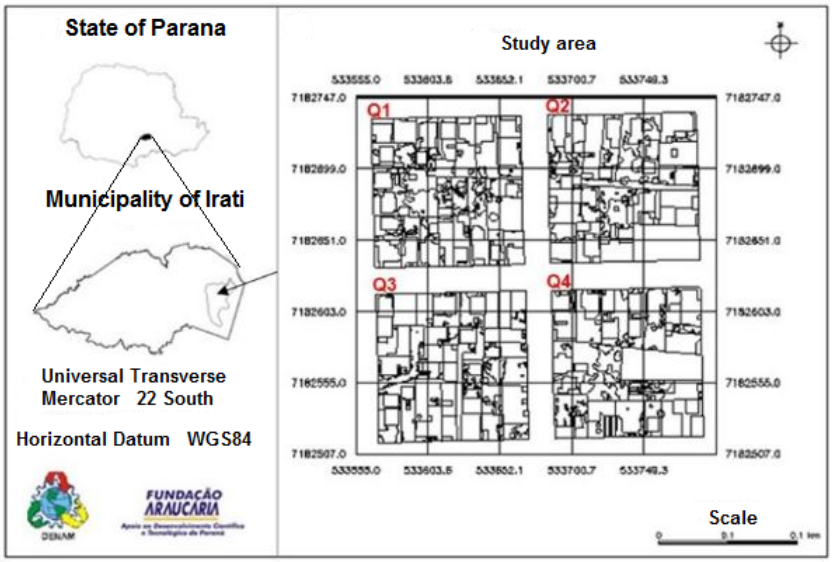
One of the most promising remote sensing techniques for urban mapping is sub-orbital remote sensing by means of Remotely Piloted Aircraft (RPA), which are aircraft piloted through a Remote Piloting Station (BRAZIL, 2015). Among the advantages of using the RPA are the small size of the aircraft, low operating cost, good performance at low altitudes, flexibility in maneuvers, in addition to the effortlessness adaptation to the needs of each project. The use of software makes it possible to monitor and map the transformation of natural resources in urban centers. In this way, it is possible to estimate, through remote sensing techniques in conjunction with GIS, the soil permeability rates, and the consequent impact generated on the ecosystem by the impermeable areas.

This work aims to use images obtained by RPA for the detection of targets that are part of the landscape, in particular for the analysis of permeability rates of blocks and lots that aim to assist the management and planning of land use and occupation. The working hypothesis for conducting this research was that very high-resolution images obtained by low cost RPA have sufficient spatial resolution and allow obtaining the soil permeability rate at the individual lot level and, therefore, have the potential to monitor and assist in the inspection of the internal permeability rates of urban lots.

Materials and methods

The study area covers four blocks (Figure 1) located in the Rio Bonito district totaling 0.04 km^2, in the urban

Figure 1 – Study area location. Indication of the city of Irati on the map of the State of Paraná and the urban area of the city. Indication of the four blocks (Q1 to Q4) under study and their approximate location within the urban perimeter (arrow).



Source: The authors.

perimeter of Irati, state of Paraná, 156 km from the capital Curitiba, and its central location coordinates are 7,182,651.0 m and 533,700.7 m UTM timezone 22, horizontal datum WGS84.

Such blocks were selected for the present study, because the Rio Bonito neighborhood has a 40% permeability rate exigency within the lots, as it is a risk area and has a history of flooding. It is also observed that this set of urban lots follows a pattern with gardens and/or backyards that is not a characteristic of other regions of the city.

Aerial photographs of very high spatial resolution (3 centimeters) were obtained using the RPA DJI Phantom 3 Standard (Figure 2).

Figure 2 – RPA model DJI Phantom 3 Standard.

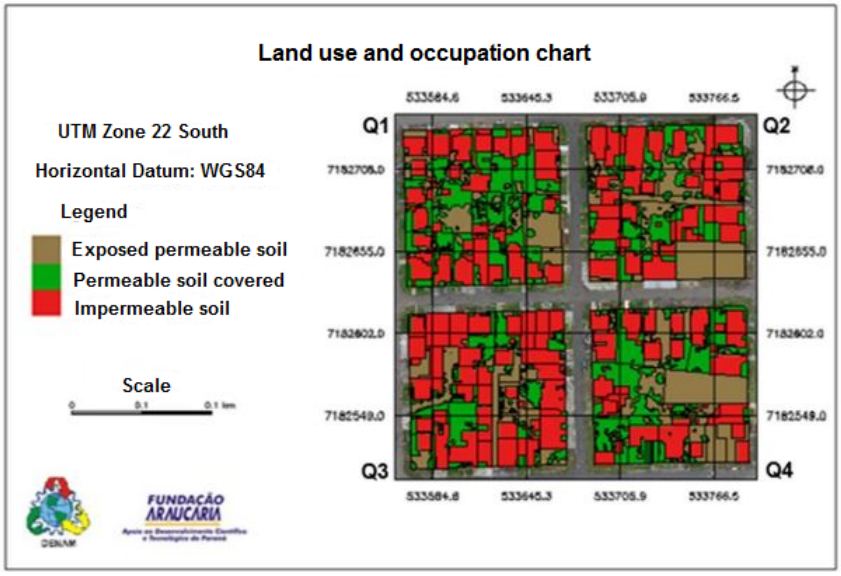
Source: The authors.

Flight planning was conducted by the Pix4D Capture app installed on a smartphone with Android operating system. The images were obtained at 80,00 meters height with 80% longitudinal overlap and 60% lateral overlap, in JPG format with a resolution of 2048×1535 pixels, 72DPI, with the DJI Phantom 3 camera. Next, the processing and restitution of the photographs and generation of the orthomosaic were carried out, using 5 control points, in the Agi Soft Phtoscan application generating a file in the geotif format.

The images with very high spatial resolution were imported into the public domain SPRING application, version 5.4.3. Next, patterns of different intra-urban targets were recognized. The interpretation and classification of the images were performed using the technique of manual vectorization on canvas, followed by an association of the polygons to the pre-defined classes. Three classes of land use were identified: impermeable areas, exposed soil and soil cover with vegetation. The two classes of soil (exposed and covered with vegetation) were associated with a broader class called permeable areas. The land use and occupation map (Figure 3) containing the distribution of the three classes was prepared using the same software, with its respective legend.

In the first stage of the study, the values in square kilometers and their respective occupation rates (%) of the permeable and impermeable areas of the four blocks were determined, totaling 87 lots.

Figure 3 – Classification of land use and occupation map obtained from the Study Area. The four evaluated blocks indicated by numbers from Q1 to Q4.



Source: The authors.

The second stage of the study consisted of a confrontation with the municipal legislation regarding the minimum soil permeability rate determined for the study area. Due to the absence of constructed areas, only wasteland, five of the 87 lots were excluded from the study, totaling 82 for confrontation, which makes the study more applied in the sense of inspection under conditions of internal use of the lot after the construction of buildings.

Results and discussions

The use of very high spatial resolution images has a eleveted level of detail, reliably enabling that the interpreter to detect and recognize different urban targets. The result of the interpretation and classification of land use and occupation is shown in Figure 3.

The impermeable areas correspond to the pavements of streets, buildings, patios and sidewalks. As they do not have a permeability capacity, they prevent the infiltration of water in the soil, resulting in an increase in the rate of runoff and its speed, contributing significantly to the occurrence of floods. The permeable areas correspond to trees and undergrowth vegetation or exposed soil.

In this study, the results of land use and occupation rates showed that permeable areas represent 52.84%, with 25.29% presenting exposed soil and 27.55% covered soil (Table 1).

Table 1 – Classes of land use and occupation in Km^2 and percentages.

Land use and occupation	Km^2	%
Impermeable area	0.01895	47.16
Permeable area	0.02123	52.84
Total area	0.04017	100.00

Source: The authors.

Although the result found for permeable areas is superior when compared to impermeable areas, the same is not satisfactory, since five private lots without built areas were identified and that in the future when occupied can change the panorama of the permeability rate of the study area. In this way, these five lots were removed from the study for comparative analysis with the minimum rates required by the local City Hall for the neighborhood in question. Around the four blocks analyzed, all streets are paved with asphalt, an important factor to be considered about the impermeability of urban regions.

A similar study, carried out in two neighborhoods in the city of Londrina, analyzed the waterproofing through the mapping of land use and occupation using satellite images, with maximum spatial resolution ten times lower than that used in the present research. The results of this study showed that around 51.4% of the soil was waterproofed, including paved streets, with consequent compaction and difficulty in percolating the water into the soil (CAUDURO, 2014).

According to the information presented in the City Master Plan, the study area is located in the urban consolidation macro-area, presenting a complete or satisfactory infrastructure. The zone in which the study area is located is in residential area 1, as it is a low density zone, the minimum permeability rate required for the region is 40%, and the use and occupation of the soil is permitted by single-family homes and two-family homes (IRATI, 2016a). The results of the analysis of permeability rates from block to block, lot to lot, are shown in Figure 4, highlighting the cut line or minimum limit required for these rates according to the city master plan.

According to the data shown in Figure 4, it can be seen that approximately half of the lots of the evaluated blocks, especially blocks 2 and 3, which have a permeability rate lower than required by law, a factor that contributes to the runoff of rainwater and compromises the volume of nearby rivers. A similar work carried out in blocks that set the historic center of Irati showed a permeability rate of 45% (LECHIU; OLIVEIRA FILHO; SOUSA, 2012).

Among the 82 lots analyzed in the study, 52.43% fulfill the established of municipal legislation. However, it was possible to identify in RPA images of very high spatial resolution (3 centimeters), that some lots stand out for presenting an extremely high impermeable area, with percentages very close to 100% of the lot, Figures 4(b) and 4(c). The images obtained by ARP in this study have about 17 times more resolution than the images available on the market, with higher spatial resolution obtained by orbital platforms, such as those from the GeoEye satellite, for example, which has a spatial resolution of around 50 cm. Due to the very high spatial resolution and low flight height, the level of detail achieved with the images produced by RPA is elevated, allowing the detection and recognition of different urban targets in a more reliable way by the photointerpreter

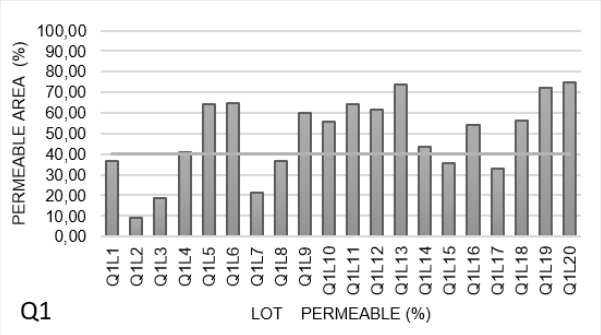
Conclusion

The results evidence that it is possible to evaluate the internal permeability rate of urban lots using RPA images with very high spatial resolution.

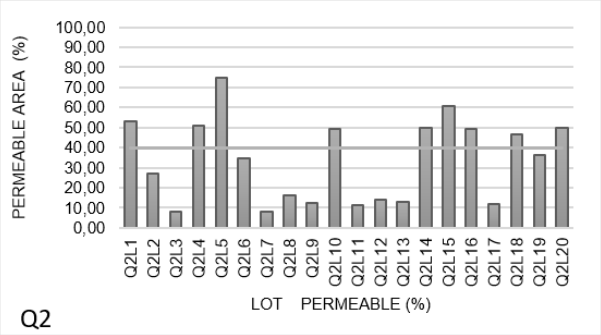
Another important issue is the autonomy that municipalities or even third-party companies can have the operation of this tool both in the frequency of surveys and flight altitude and, consequently, resolution and scale, as long as the ARP is registered with ANAC (National Agency of Civil Aviation) and ANATEL (National Telecommunications Agency), flights approved by SARPAS (Request for Access to Remotely Piloted Aircraft) and pilots registered on the same platform. Otherwise, the imaging is irregular and cannot be used for inspection purposes (or any other

Figure 4 – Results of analysis of the permeability rates of blocks Q1, Q2, Q3, and Q4, and cut line showing the minimum permeability rate required for the region.

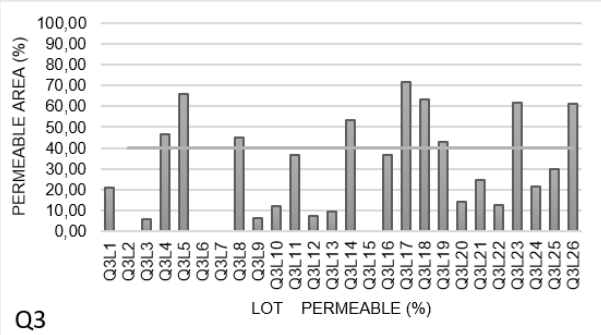
(a) rates of blocks Q1



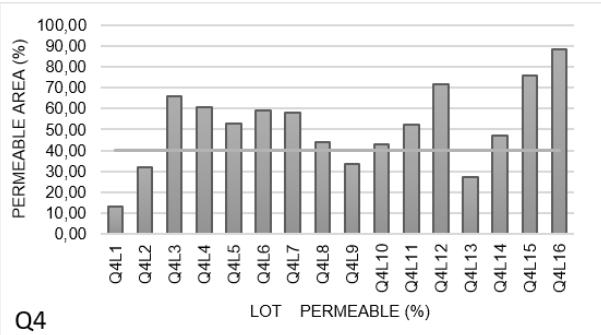
(b) rates of blocks Q2



(c) rates of blocks Q3



(d) rates of blocks Q4



Source: The authors.

purpose), risking the pilot, city hall and/or company to suffer the penalties provided by law.

In this way, RPA images can be considered as useful tools in studies of the urban fabric, especially for the analysis of permeability rates of blocks and lots, with perspectives to assist management, inspection, and planning of land use and occupation. It is worth mentioning that the work also contributes to the reading of the tendencies of decrease of free spaces vegetated intra-lot and, with the application of the methodology in large scale in the urban area of the municipality, it allows to quantify this projection in time record and to periodically update the requirements laws regarding the use and occupation of land and the demands for permeability.

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