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Evaluation of impacts of the occupation, compatibility and adequacy process applied to buildings in residential yards on the construction site code of Palmas city – Tocantins state (TO).

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ABSTRACT

The aim of the present study is to evaluate the progress of the occupation process applied to residential yards of Palmas City – Tocantins State (TO) in the light of the legislation providing on parameters and guidelines for residential buildings in this municipality. Aerial and satellite images, as well as tools of the geographic information system (GIS), at high resolution standards, were used for data processing and collection. Study site encompassed yards 407 North, 504 South and the Bertaville Sector, which are located in different regions of the city and at different occupation stages. Seeking to attest to the potential of the generated products in terms of photointerpretation, Geometric and geographic accurate measurements were turned into field images in order to attest to the photo-interpretation potential of the generated products. Impacts of rainwater surface runoff on the study site were evaluated based on urban index data, occupancy rate, built-up areas, waterproofing rates and urban voids, confronted with construction site code provisions.

Keywords: Municipal Construction Code. Urban Indices. Unmanned Aerial Vehicle (UAV).

1 INTRODUCTION

According to Palmas Municipal Institute of Urban Planning - IMPUP – (2017), Palmas, the capital of Tocantins State, was designed based on a modernist urbanistic project that covered a total urban area of 11,085 hectares, which could house approximately 1,200,000 inhabitants. This project predicted occupation and densification phases by setting growth and development guidelines on a densified core-axis focused on urban services. However, the occupation process did not follow the programmed guidelines, not even at its broadening stages, neither the planned densities. Such a fact accounted for generating several urban voids in central regions. On the other hand, peripheral regions showed dense concentration of low-income populations.

Based on Diniz et al. (2015), accelerated urban growth without implementation of an integrated construction site code focused on irregular installation of hundreds of allotments by the roads, without any specific criteria, and on the installation of partial infrastructure, is a condition that does not fulfill the security, comfort and hygiene demands of both users and other citizens. Accordingly, and based on (Rodovalho et al. 2019), the municipal Executive power aims at promoting social inclusion by boosting the occupation of urban voids. However, just as observed in other Brazilian municipalities, market private interests are more important than those of collectivity, and it makes the access to both urbanized land and housing harder for lower income populations.

Thus, public debate gets almost fully limited to economic-issue aspects, such as public expenses and the very old debate between the public and private sectors about the efficiency of producing and allocating resources (SOUZA, 2009). Therefore, the study about the match and adjustment of such buildings to the construction site code works as important tool for urban planning and to make access to the right of housing feasible. It is essential meeting particular interests of involved parts to fulfill public interests by improving the quality of city and by providing opportunities to lower income populations. It is so, because such a process allows improving infrastructure by planning on how to distribute municipal incomes.

High-resolution aerial images gotten by unmanned aerial vehicle – UAV – were used in the present study. According to Melo (2016), the continuous evolution of UAV platforms has allowed this emerging technology to be used for several applications, such as: agriculture and livestock, surveillance and traffic jam control, monitoring of hazardous events (wildfire, and natural disasters, advertisement campaigns and real estate market). Studies in this civil engineering field are recent, and they emphasize roads' monitoring (BARROS et al., 2017), identification of pathologies in asphaltic paving (PARENTE et al., 2017), inspection of construction sites (MELO, 2016), and mapping process applied to several projects (ALMEIDA, 2014).

According to Siebert and Teizer (2014), versatility and low cost are some of these tool's main features, because previous surveys enable achieving a totally flexible temporal resolution. It is so, if one takes into account that it is likely carrying out several flights at different times of the year over the same site; they are cheaper than the aerial-surveying by manned aerial vehicles. Furthermore, it is likely acquiring higher-resolution aerial images free from atmospheric-obstacle interferences, such as cloudiness and gases. Therefore, one can get images with high overlapping degree, a fact that allows the tridimensional view of objects based on two, or more, plane images taken from different positions (stereoscopy).

As for Guiffrida (2015), the potential to be used is closely related to its low costs, high mobility, provided security, proximity to the photographed object, acquisition speed and data transfer. This potential allows adopting monitoring procedures over the year based on images; it can be used in situations where manned inspections are unfeasible. Besides corroborating the identification and correction of conditions and/or safe acts, it also helps predicting hazardous events.

According to Udin and Ahmad (2014), aerial-surveying has increased the demands, mainly due to its small digital format. The platform provides several flight modes, such as manual, semi-automated or fly-by-wire ones; they are easy to be developed and cheaper than manned aerial survey, besides providing higher security levels.

Accordingly, the aim of the present study was to assess the application of images generated by unmanned vehicle (UAV) to match and adjust buildings in Palmas region (TO) to its municipal construction site code and to its influence on rainwater surface runoff.

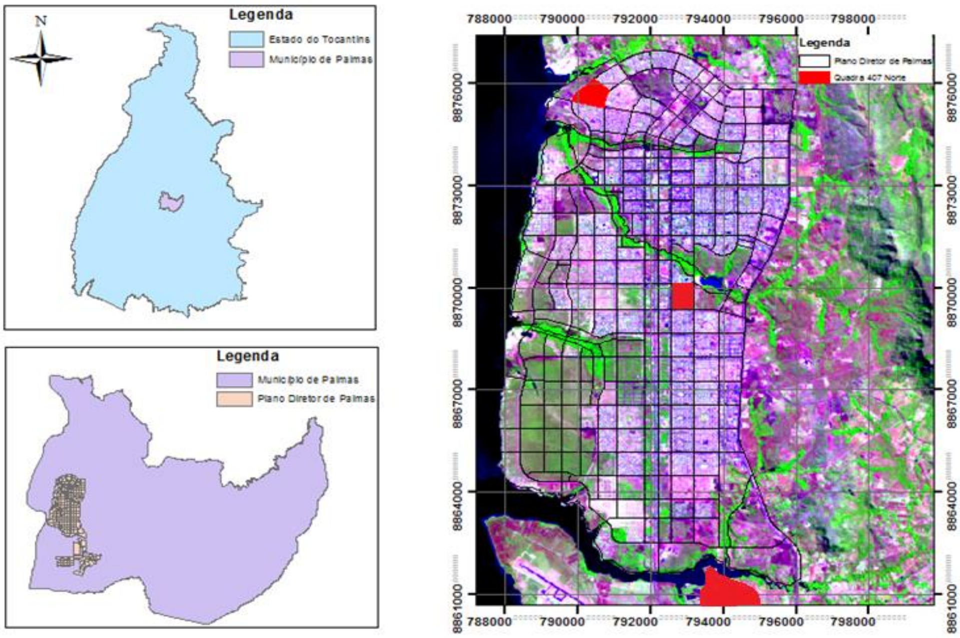
2 MATERIALS AND METHODS

Materials and methods used in the study are herein introduced, as well as the study site and the reasons motivating the choices made for fieldwork. It is also important pointing out the features and specificities of equipment adopted for image capturing, as well as describing the software used in this research and its applications at each study stage, in flight planning, in parameters and techniques used for image capturing, orthomosaic processing and result analyses.

2.1 STUDY SITE

The study site encompasses yards 407 North and 504 South, as well as the Bertaville Sector, which are located at different regions of Palmas City, Tocantins State (Figure 1).

Figure 1. Chart of study objects



Source: Research archives

Yard 407 North covers total area of 508,600 m², because it is an old allotment with high occupation rate; it was launched and registered back in July 20, 1998. The second yard (504 South) is located in Palmas central region, and it covers 409,762.58 m; it is fully occupied. The last study site is located in the city's peripheral zone and covers total area of 601,631 m²; it remains at initial occupation phase. The choice made for the referred sites is linked to their initial and final occupation data, as well as to their location within the city's urban arrangement.

2.2 MATERIALS

2.2.1 UAV EBEE SOFTWARE FOR FLIGHT AND IMAGE PROCESSING

The unmanned aerial vehicle model eBee (Figure 2) was adopted for image collection. The aircraft has two platforms with specific sensors coupled to it; they allow capturing the photographic images. The aircraft has sensors that allow equipment stability during the missions, as well as the transmission of data that enable the direct follow-up of on-going flights.

Figure 2. eBee model unmanned aircraft.

Source: research archive

Flight planning was elaborated in the base station according to the following set: software eMotion 2, which accounted for flight programming and aircraft's trajectory conduction; a transmission antenna that allowed flight follow-up at real time and landing commands, direction changes or image capturing. The software's interface shows important information about battery level, environmental temperature, altitude, flight duration and speed, wind speed, resolution, and longitudinal and latitudinal overlapping of the assessed sites, altitude and radio link. The aircraft also had specific software (Pixe4D) to process images and to generate orthorectified mosaics. Points captured by the aircraft's GPS were associated with each one of the images taken during this process.

2.2.2. BASE

The aircraft's flight control base comprised an aluminum case coupled to a notebook with the eMotion 2 software installed and configured in it, as well as a radio transmitter (Figure 3). The machine linked to the transmitter radio allowed controlling and watching all stages of the programmed flight.

Figure 3. Flight control base.

Source: research archive 1

Continuous communication ensures that information is received and sent to an aircraft.

2.2.3 IMAGE CAPTURING DEVICE (CAMERAS)

The camera used to capture images presented the following features: Canon model RGB S110 adjusted and compatible to the eBee system, and the orthomosaic formation application; sensor Live MOS de 12.3 megapixels with gama ISSO ranging from 100 to 6400 capable of recording Raw images (12-bit compression without losses), JPEG, JPEG + RAW, image stabilizer and maximum shutter speed of 1/4000s – it can shoot up to 3 frames per second.

2.2.4 FLIGHT PLANNING AND TRAJECTORY

The plan set for the current study aimed at getting images to ensure the best distinction of objects on the surface and the highest accuracy to survey occupied sites and buildings' setbacks. Flights were performed based on image overlapping at longitudinal order of 50% and lateral order of 75%. Image overlapping ensured that the lines could be overlapped based on analog points between two or more images in the common area to form a single block.

2.2.5 IMAGE CAPTURING

The aerial platform captures photographic images up to 12Km² wide and in smaller sites by flying at lower altitudes; they can reach 3.5cm per pixel. The engine is automatically turned off at the time to take pictures to increase aircraft stability and to avoid engine vibrations over the camera.

The properly georeferenced mosaic was gotten after a whole series of stages that have encompassed the removal of errors and distortions caused by the image capturing process. The aim was to drive figures in comparison to one another and in comparison to the complete scene. This process also allowed making radiometric adjustments in colors to avoid discontinuity between them.

Image processing was carried out in software compatible to the aircraft's sensor model; it has a GPS navigation device coupled to it. This GPS makes it possible getting the control points in the image itself, which is referenced in the UTM DATUM WGS84, FUSO 22L system of coordinates.

2.2.6 ORTHOMOSAIC DATA SURVEY

After generating the mosaics of the identified land fractions in arcGIS (2017) software, it was possible creating two polygons for each building; one polygon concerned the total area and the other regarded the built area. The editor tool for field calculations in arcGIS (2017) software was used to find areas and perimeters; the "measurement" tool was applied to buildings' setbacks.

Mosaics also allowed identifying urban voids in each of the assessed yards, as well as soil coverage in these areas and identifying inadequate discharge points for urban solid waste. After finding the soil coverage and occupation rates, it was possible finding the yards' weighed sealing rate and, consequently, their runoff potentials – it triggered the discussion about these values and their impacts.

The recorded results were compared to provisions on the Municipal Construction Site Code after vectoring the buildings, namely: constructed area, setbacks, sealing rates. It was done in order to assess the potential use of these products in these buildings' match and adjustment studies.

2.2.7 FIELD DATA SURVEY

The twenty (20) chosen points to assess the reliability of data extracted from the orthomosaic in a quite well-distributed way. These points lacked interferences and obstacles that allowed the proper measurement of roads, sidewalks and land plots' width; thus, it subsidized the reliability of the tool applied to the proposed survey.

2.2.8 RUNOFF COEFFICIENT CALCULATION (C)

According to Tucci (2005), there is a corresponding runoff coefficient for each surface coverage type in urban zones, as shown in Table 1. Coefficient values recorded for each described surface coverage type were used to calculate the weighed runoff coefficient of the herein assessed yards.

Table 1. Runoff coefficient recorded for each soil coverage type

Soil coverage class	Runoff coefficient (C)
Asphalt	0.83
Ceiling	0.85
Sidewalk	0.88
Vegetal coverage	0.20
Empty land	0.20

Source: Tucci, 2005

The weighed coefficients were calculated based on the equation below, according to values recorded for coverage areas resulting from mosaic vectoring and coefficients shown in **Table 1**.

$$Cp = (Ca \; x \; Pa) + (Cc \; x \; Pc) + (Cs \; x \; Ps) + (Ct \; x \; Pt) + (Ci \; x \; Pi)$$

Wherein:

$Cp = Coeficiente\ de\ escoamento\ ponderado$

$Ca = Coeficiente\ de\ escoamento\ para\ asfalto (tabela\ Tucci)$
$Cc = Coeficiente\ de\ escoamento\ para\ concreto\ (tabela\ Tucci)$
$Cs = Coeficiente\ de\ escoamento\ para\ solo\ (tabela\ Tucci)$
$Ct = Coeficiente\ de\ escoamento\ para\ telhado (tabela\ Tucci)$
$Ci = Coeficiente\ de\ escoamento\ para\ intertravados (tabela\ Tucci)$
$P = Percentuais\ de\ cada\ tipo\ de\ superfície\ obtido\ por\ meio\ das\ imagens$

These values were associated with each other to get to the construction runoff recorded for each yard by getting to the coefficient weighed to each one of the yards.

$$Q = 0{,}278 \; x \; C \; x \; I \; x \; A$$

Wherein:

$Q = vazão\ de\ contribuição\ (m^3/h)$
$C = coeficiente\ de\ deflúvio\ de\ cada\ quadra$
$I = intensidade, duração\ e\ frequência\ das\ chvas\ (mm/h)$
$Q = área\ de\ contribuição\ de\ cada\ quadra\ (Km^2)$

3 RESULTS

3.1 ADJUSTMENT TO THE CONSTRUCTION SITE CODE

As already mentioned, buildings were turned into vectors to extract the following guidelines: land area, built area, perimeter, and buildings and land setbacks. It was done to allow analyzing the soil occupation rate pre-established in the Municipal Construction Site Code and in law n. 386, from February 17, 1993, which provides on the division of the Urban Area of Palmas Municipal Headquarter in Zones of Use, as well as on other provisions.

The assessed areas were classified as Residential Areas (RA); uses applied to Single Family Housing were a) Single Housing; b) Sprouted Housing; c) Serial Housing.

According to law n. 386, built areas in these regions must be represented in only 60% of the land, in the first pavement. Calculation to get to this rate lies on the division of the land's projected area. All lands with buildings were turned into vector in all yards; it corresponds to the total of 816 land plots in yard 407 North, of 754 in yard 504 South and of 309 in Bertaville Sector.

Table 2 introduces the results recorded for the match of buildings concerning soil occupation and sealing in the yard. According to the Municipal Construction Site Code, the maximum occupation rate recorded, or residential areas (RA), reached 60% of the land plot. It was done by respecting the minimum mandatory setbacks and 25% soil sealing index.

Table 2. Occupation rate and sealing of fractions surveyed in each yard.

Number of analyzed land plots					
Yards	**Soil occupation rate ≤ 60%**	**Soil occupation rate > 60%**	**Sealing rate ≥ 25%**	**Sealing rate < 25%**	**Total of land plots**
504 South	289	465	313	441	**754 plots**
407 North	307	409	309	507	**816 plots**
Bertaville	217	92	125	184	**309 plots**

Source: Elaborated by the authors

It is possible observing that the number of buildings meeting the defined maximum occupation rate is small. The two yards whose occupation process dates back to the early city's occupation, 504 South and 407 North have rates that overcome 60% of buildings that are not in compliance with provisions on the Municipal Construction Site Code. The scenario in the third yard, Bertaville, can be linked to the initial search for the necessary licenses for a construction site to be implemented.

With respect to land plots' setbacks, the criteria set for project approval parameters are mandatory - the sidewalk limit around the built area is mandatory (5.9m free, 2.00m on the back, 1.50m in the sides, and null in other dimensions).

If one assesses Table 3, it is possible observing that buildings meeting the front side setback demands did not exceed 10% in the two yards that had their occupation process dating back to earlier times (504 South and 407 North). With regards to back and lateral setbacks, the three yards presented approximately 80.51% of buildings that are in compliance with the provisions. Only 42.89% of buildings have met all mandatory minimum setbacks, despite the high rate of compliance with the setbacks, mainly the lateral ones.

Table 3. Values recorded for front side setbacks surveyed in each one of the yards.

Rate of analyzed buildings			
Yards	**Front side setback ≤ 5.0m**	**Front side setback ≥ 5.0m**	**Total of land plots**
504 South	**704**	**50**	**754 plots**
407 North	**749**	**67**	**816 plots**
Bertaville	**186**	**122**	**309 plots**

Source: Elaborated by the authors

It is worth highlighting that the generation of useful geometric information gotten from sensory remote system, based on UAV. It was used to identify the technically and economically match and adjustment of buildings to the construction site code in order to reach the aim of producing programmed low-cost high-resolution images without cloud-cover interference.

One can observe that time can be reduced by taking such a factor for matching and adjusting buildings. Such time reduction is linked to the difficulty level set for getting these data without aerial images. However, it must be said that buildings' matching and adjustment shall not depend on image obtainment. There are cases whose evaluation, *in loco*, is much faster and efficient; however, the larger and more disperse assessed areas, the greater the applicability of the recorded images and the higher the time saving in this process. The use of these images can be justified by the difficulty in having access to area in and outside the urban perimeter.

3.2 YARDS' CONTRIBUTION RUNOFFS

The process to turn mosaics into vectors allowed calculating the weighed runoff coefficient of each one of the assessed yards. Table 4 shows the rates surveyed for each one of the identified coverage types.

Table 4. Rate of coverage of each one of the yards.

Rate of surface coverage of the yards					
Yards	**Asphalt (%)**	**Concrete (%)**	**Ceiling (%)**	**Natural Land (%)**	**Grass (%)**
504 South	**14.55%**	**28.62%**	**29.74%**	**10.96%**	**16.13%**
407 North	**13.60%**	**31.21%**	**25.25%**	**9.17%**	**20.77%**
Bertaville	**12.60%**	**22.82%**	**20.32%**	**31.81%**	**12.45%**

Source: Elaborated by the authors

Simulation based on confronting runoff contribution data (surface runoff) calculated according to the weighed runoff coefficients opened room for interesting results if one takes into account the current coverage situation of the yards at hypothetical runoff concerning the coverage rates provided on the construction site code. The table below shows runoff data associated with each runoff coefficient recorded for both yards.

Table 5. Yards' contribution runoffs

Yards' contribution runoffs					
Yards	**C (current situation)**	**C (for construction site code)**	**IDF – Rainfall intensity, duration and frequency (mm/h)**	**Runoff contribution (m^3/s) – current situation**	**Runoff contribution (m^3/s) – to the construction site code**
504 South	**0.68**	**0.58**	**150**	**11.62**	**9.92**
407 North	**0.64**	**0.61**	**150**	**13.61**	**12.97**
Bertaville	**0.55**	**0.51**	**150**	**13.76**	**12.76**

Source: Elaborated by the authors

Runoff contribution generated by surfaces results from rainfall surface runoff. The generated volume is a datum closely related to the city's drainage system dimension, in other words, based on this specific datum, it sets the number of manholes, gutter depth and the diameter of galleries that could guide the released waste to its destiny.

If one observes the results, it is possible inferring that dimensioning the devices composing the drainage system, based on the project of sealing data, soil plot using and occupation provided on the construction site code. It would bring a sub-dimensioned system to the real runoff situation.

4 CONCLUSION

The collection of land surface images through the UAV tool used in this research bring along innovation, adds fastness and accuracy to this process, despite the possibility of analyzing distances. Besides, it sets new time and spatial resolution standards, since it provides the possibility of making a fast revisit to achieve a higher level of imaged area details; it allows clarifying uncertainties at the vectorization phase.

Based on the visual evaluation of images collected by the RGB sensor, it was possible observing the great richness of information. It has facilitated the process to turn urban drainage components into vectors. With respect to components' vectorization, the traditional method measures each object, in separate, until it covers the whole extension of the yard, whereas the UAV technology enables quickly extracting the 'quantitatives' after mosaic generation. The tool meets the proposition of producing low-cost higher-resolution images in a programmed form without interference by cloud covering – it confirms its technical and economic feasibility.

According to the survey of stretches' length, there is a slightly significant difference in rates between data surveyed in the generated mosaics and field survey.

Therefore, the methodology was promising because its presents fast and accurate results. It can be used as subsidy in the process to assess the match and adjustment of the drainage system to guidelines in Palmas' Municipality project – TO.

However, the herein used tool does not aim at replacing the conventional methodology used and at adding new information to the currently applied method. It maximizes information through georeferenced images that could be consulted at an opportunistic moment, a fact that makes it possible clarifying uncertainties found at the time to assess the match and adjustment of urban drainage components, such as contribution areas, gutter extension, and the position and number of manholes.

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