Index of Propensity to Flooding Applied to the Municipality of Duque de Caxias, Metropolitan Region of Rio de Janeiro

Indice de Propension des Alagaments Appliqués a la Municipalité Duque de Caxias, Région Métropolitaine de Rio de Janeiro

Francis Martins Miranda[1]; Matheus Martins de Sousa[2]; Osvaldo Moura Rezende[3]; Ana Caroline Pitzer Jacob[4], Marcelo Gomes Miguez[5] & Assed Naked Haddad[6]

[1]PEA, Federal University of Rio de Janeiro (francis@coc.ufrj.br); [2]PEA, Federal University of Rio de Janeiro (matheus@hidro.ufrj.br); [3]PEA, Federal University of Rio de Janeiro (omrezende@coc.ufrj.br); [4]AquaFluxus Environmental Consulting in Water Resources (caroline@aquafluxus.com.br); [5]PEA/POLI, Federal University of Rio de Janeiro (marcelomiguez@poli.ufrj.br);[6] PEA/POLI, Federal University of Rio de Janeiro (assed@poli.ufrj.br);

RÉSUMÉ

La présente étude présente le processus méthodologique et l'application d'un indice de propension des inondations (IPA) en tant qu'outil d'identification et de hiérarchisation des régions les plus exposées aux défaillances du système de microdrainage urbain. L'indice est constitué d'indicateurs se rapportant au service du service de microdrainage urbain, à la déclivité pour le drainage de la région et au nombre de personnes exposées à d'éventuels dommages causés par la défaillance du système. La grille statistique de l'IBGE a été utilisée comme unité d'étude et la municipalité de Duque de Caxias, dans la région métropolitaine de Rio de Janeiro, a été choisie. Les résultats de l'IAP sont présentés par quartier en fonction des classes de l'indice et servent d'outil pour l'adoption de mesures structurelles et non structurelles en matière de gestion des risques d'inondation en milieu urbain.

ABSTRACT

This study presents the methodological process and application of an Index of Flood Propensity (IFP) as a tool for the identification and hierarchization of regions more prone to failures in the urban drainage system. The index consists of indicators referring to the service of urban drainage, slope for drainage of the region and the number of people exposed to possible damages caused by the failure of the system. As a unit of study was used the statistical grid of the Brazilian Institute of Geography and Statistics (IBGE) and as a case study the municipality of Duque de Caxias in the Metropolitan Region of Rio de Janeiro. The results of the IFP serve as a tool for the adoption of structural and non-structural measures in urban flood risk management.

KEYWORDS

Duque de Caxias, Flood index, Multicriteria method, Urban drainage, Urban floods

1 INTRODUCTION

Flooding can be caused due to a failure of the urban drainage system, even if subjected to precipitation below the designed recurrence time. The main reasons are installation errors, irregularities, under-dimensioning of infrastructures, clogging, obstructions or changes in land use in the area of contribution. In order to diagnose the current situation of urban drainage services, it is necessary to carry out a technical cadastre of the systems' networks and devices for all urban areas at the municipal level. However, the Brazilian reality testifies to the non-fulfillment of this obligation, in addition to possible incompatibilities between records in the cadastre and the implemented system.

Thus, this study presents a simple methodology to determine urban drainage services using secondary data, and then a hierarchization for determining areas that are more prone to system failures. The so-called Index of propensity to flooding (IPF) was developed for the municipality of Duque de Caxias – RJ as a tool to support urban planning, seeking to reduce losses of floods. The municipality of Duque de Caxias is located in the Baixada Fluminense lowlands and Metropolitan Region of Rio de Janeiro (MRRJ). Formed by three important river basins for the region context, the municipality is marked by high susceptibility to flooding due to its physiographic characteristics and occupation process.

2 METHODOLOGY

The proposed methodology is based on the application of a multicriteria analysis in the formulation of indicators that are part of an index representing the propensity to flood phenomena, indicating regions that present a natural difficulty for drainage due to low slopes, in combination with the existence or not of the urban drainage system. The IPF indicators and its weights are presented in Equation 1.

$$IPF = (0{,}5 \cdot I_{SD}) + \left(I_E \cdot (1 - I_{MiS})\right) \cdot 0{,}5 \quad (1)$$

Where:

- IPF – Index of propensity to flooding;
- I_{SD} – Indicator of slope for drainage;
- I_E – Indicator of exposure;
- I_{MiS} – Indicator of attendance of urban drainage service;
- (1- I_{MiS}) – Indicator of non-attendance of urban drainage service.

The statistical grid of IBGE is used as a study unit. Available in 2016, the grid presents data of population, gender and number of households of the 2010 census in boxes of 200x200m for urban areas and 1x1km for rural areas. The development of the Indicator of Slope for drainage was based on a Digital elevation model (DEM) for the municipality in the scale of 1:10,000. The Indicator of Exposure (IE) was calculated directly with the grid data, while the Indicator of Urban Drainage Service (IUDS) was calculated for the Censitary Sector and subsequently designed for the statistical grid. The following will be presented the characterization of the municipality used as case study and methodological process of the FPI indicators

2.1 Indicator of Urban Drainage Service (IUDS)

The urban drainage service in the municipality of Duque de Caxias was qualified according to the percentage of houses that have opening that gives access to the drainage networks. This information is presented in the IBGE (2010) census spreadsheet called "Entorno 01_uf", under the variables: V032-Own permanent private house-there is a manhole; V033-Own permanent private house - there is no manhole; V034-Rented permanent private house – there is a manhole; V035-Rented permanent private households – there is no manhole; V036- Assigned permanent private house – there is a manhole V037-Assigned permanent private house - there is no manhole. Thus, in order to estimate Indicator of Urban Drainage Service - IUDS, the formulation presented in Equation 2 was used.

$$I_{Mis} = \frac{n^{\underline{o}}\ of\ private\ residences\ with\ a\ manhole}{n^{\underline{o}}\ total\ of\ residences} = \frac{(V32 + V34 + V36)}{(V32 + V34 + V36 + V33 + V35 + V37)} \quad (2)$$

As the study proposes to analyze the propensity to the failure of the urban drainage system, the indicator of non-attendance will be used by the service of urban drainage given by 1 less IUDS.

2.2 Indicator of Exposure (IE)

The exposure, according to the methodology adopted by the World Bank in flood risk management (Sayers et al., 2013), represents people or goods located in susceptible areas. As part of the multicriteria analysis, the population density was normalized with values between 0 and 1. However, it is considered that the maximum exposure occurs in the density value referring to the third quartile of the entire sample, in order to reduce distortions of the evaluation scale as a function of extreme values. Figure 1 shows a graph with the normalization of the IE exposure indicator.

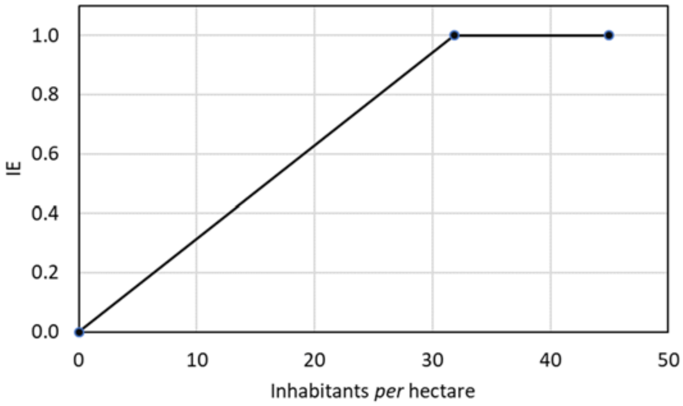

Figure 1 – Normalization of Indicator of Exposure.

2.3 Indicator of Slope for Drainage (ISD)

The slope can be considered the most important physical parameter in the definition of floodplains or flooded areas (Therany et al., 2014; Kazakis et al., 2015). Relatively flat or low slope regions presents difficulties in natural drainage and built systems should be subject to special design criteria. In this indicator, the territory is classified according to its slope for surface runoff based on parameters found in the brazilian scientific literature and legislation (EMBRAPA, 2006; RIO ÁGUAS, 2015). Table 1 presents the classes of Indicator of Slope for Drainage (ISD).

Table 1 - Classes of Indicator of Slope for Drainage and its normalized value. Source: Miranda, 2016.

Categories	Ranges of Slope	Indicator of Slope for Drainage (ISD)
Inefficient	≤ 0,5	1,00
Acceptable	0,51 – 1,5	0,75
Good	1,51 – 3,0	0,5
Very Good	3,01 – 8,0	0,5
Steep	> 8	0

3 RESULTS

All indexes and indicators are normalized, with values between 0 and 1, representing lower and higher risk, respectively. The spacialized result of the IPF indicators for Duque de Caxias is presented in Figure 2 and the IPA result in Figure 3.

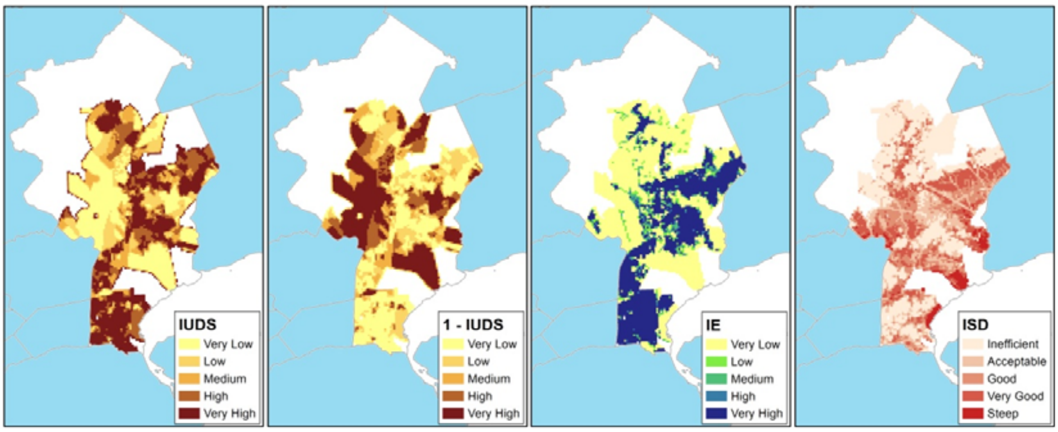

Figure 2 - Results of IPF indicators for the municipality of Duque de Caxias.

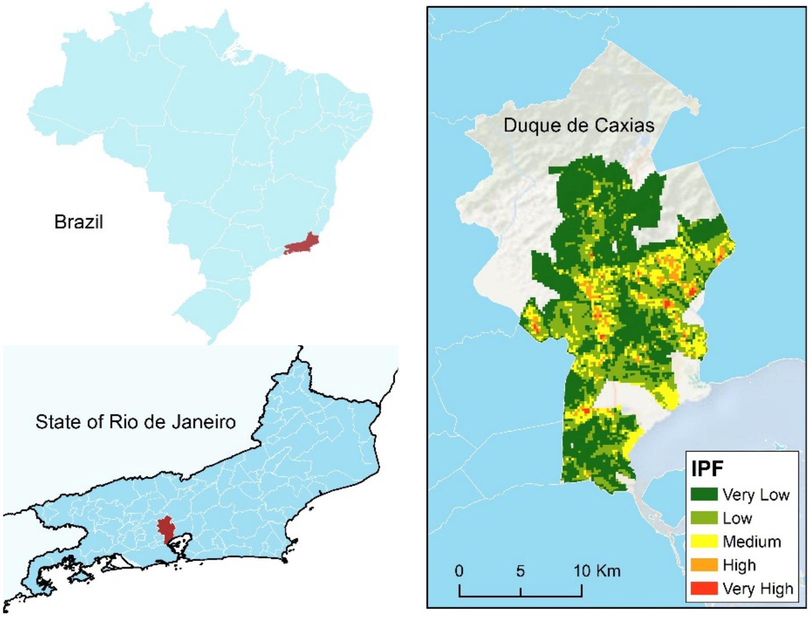

Figure 3 - IPF applied to the municipality of Duque de Caxias.

4 CONCLUSIONS

The combination of data of different natures from a Multicriteria methodology and, consequently, the elaboration of an index, enable the consolidation of complex information in a usable way for the definition and adoption of public policies. The application of IPF results in the spatialization of the propensity to flooding of urban drainage over the territory of the municipality, allowing the establishment of criteria for allocation of resources and investments in interventions that are strategic to reduce flooding risk in more vulnerable areas.

For Duque de Caxias, the application of IPA enables to point to the neighborhoods with the highest number of inhabitants in the high and very high classes of propensity of urban flooding. It can also establish guidelines for urban growth in the region. Given the lack of cadastre of the drainage system, the methodology proposed by IPF presents itself as a potential planning tool.

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