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DEALING WITH SUBJECTIVITY IN WEIGHT DETERMINATION: Climate Vulnerability Indicators

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ABSTRACT - This paper aims to propose an appropriate method to avoid subjectivity in weight determination of the indicator in the context of climatic vulnerability assessment, where the weight of each one plays a very important role due to the difference in their impact on the system. The weight can be determinate assuming that each indicator/component contributes evenly or unevenly. Thus, here the Iyengar and Sudarshan method is proposed as an option to deal with this subjectivity. This method will aid the validating the indicators at the national level, having in mind the difference between systems and quality of the data available. The method is acceptable since the results of their respective indicators do not interfere incorrectly in the maintenance of the remaining indicators. Therefore, it is a useful tool to deal with issues of subjectivity in climate vulnerability assessment.

RESUMO - Este trabalho tem como objetivo propor um método apropriado para reduzir a subjetividade na determinação de pesos dos indicadores no contexto da avaliação da vulnerabilidade climática, onde o peso de cada um desempenha um papel muito importante devido à diferença do impacto dos mesmos no sistema. O peso pode ser determinado assumindo que cada indicador/componente contribui de igual forma ou de maneira desigual. Assim sendo, aqui é proposto o método de Iyengar e Sudarshan como resposta para lidar com essas subjetividades. Este método ajudará a validar os indicadores globais a nível nacional, tomando em conta a diferença entre os sistemas e a qualidade dos dados disponíveis. O método é aceitável, pois, os resultados mostram que a variação de um indicador não interfere incorretamente na contribuição dos restantes indicadores. Portanto, é uma ferramenta de bastante utilidade para lidar com questões de subjetividade na avaliação da vulnerabilidade climática.

Keywords: Vulnerability; Indicators; Weights.

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INTRODUCTION

The weight determination for the indicators of the impact of extreme events on natural resources is one of the most critical points for a good assessment of resilience level. These pieces of evidences are notable on the validation of the global indicators to the national level, mainly if we take into account the weight issues due to the difference between systems, and the quality of the available data. Therefore, if the attribution of the weight is not transparent, on the way to reflect the main goal, the results also could not reflect the reality (Neset, 2015; Neset *et al.*, 2018). As know, the weight can be determinate assuming that each indicator/component contributes evenly or unevenly. Many researchers give equal importance to all indicators/components to have the overall vulnerability assessment (Sullivan, 2002; Mazziotta and Pareto, 2013; Pandey *et al.*, 2017). Others, give specific weight for each indicator/component, based on different methods (Iyengar and Sudarshan, 1982; Pandey and Jha, 2012; Mazziotta and Pareto 2013). However, some of these methods are based on the subjectivity understanding (Mazziotta and Pareto, 2013). Therefore, to avoid this and ensure that the variation of one indicator/component would not incorrectly dominate the contribution of the rest of the indicators/component, here we propose the alternative way to attribute the weight.

The Role of Weights on Climate Indicators

The weight determination of the climate indicators has a crucial role in the context of vulnerability assessment due to the fact that the indicators are used to monitor a set of activities and analyze the progress of established strategies over time (Birkmann and Ã, 2011; Hinkel, 2011; Martin and Becker, 2015). However, according to the situation or main goal, those indicators have different importance because each region takes into account its peculiarities. These peculiarities will define the weight of the indicator, reflecting the real situation and improves the process of vulnerability assessment.

Climate Vulnerability Indicators

Climate vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change (IPCC, 2001; Brooks *et al.*, 2005; Hahn *et al.*, 2009; Mendoza *et al.*, 2012; KC *et al.*, 2015; Pandey and Bardsley, 2015). Is also an aggregate measure which brings us the response capacity of the people and authorities to cope with climate change (Bogardi, 2004).

Definition and Selection of the Indicators

The indicators are defined taking into account a set of criteria and components to reach the main goal (Climate Vulnerability Index). Here, we identified and selected twelve indicators based on three criteria over the four components: exposure, sensitivity, adaptive capacity, and governance (Table 01).

Table 01 – Selected indicators per component based on three criteria.

Component	N.	Indicator			Interpretation
		Measurability	Transparency	Linkage	
Exposure	E1	Extreme events of floods per year (#)			The exposure of the system to this event due to his geographic location (risk level).
	E2	Extreme events of droughts per year (#)			The exposure of the system to this event due to his geographic location (risk level).
	E3	Extreme events of windstorms per year (#)			The exposure of the system to this event due to his geographic location (risk level).
Sensitivity	S1	System affected by extreme events per year (%)			The impact over the system in terms of expansion/size (coverage area).
	S2	Loss and damages in the system per year ($)			The economy and physical impacts over the system. Existence of resilient (necessary budget).
	S3	Population Density (#)			People affected around the system.
Adaptive Capacity	AC1	Institutions providing financial support (#)			Organizations with willingness to invest on adaptation over the System (funding).
	AC2	Institutions providing technical support (#)			Operated institutions to cope with the negative impact on the system (knowledge and human resource).
	AC3	Research institutions involved on climate vulnerability (#)			Investment on researchers to cope with climate issues (universities and others).
Governance	G1	Local management committee (#)			The existence of management institutions in operation. Level of the organization to cope the climate issues.
	G2	Legal policies approved (#)			Specific legislation on climate issues in the system (approved statutes).
	G3	Climate change adaptation plans and strategies (#)			Commitment. Influence of the committee on management process over the System.

As data to collect, Exposure is the number of events which affect directly in the system. Sensitivity is the quantity of loss and damages in the system (Krishnamurthy *et al.*, 2014; Koutroulis *et al.*, 2018). The adaptive capacity will be the number of existent institutions or organizations to support the system, and Governance the existent structure or mechanism to cope with extreme events (Marília *et al.*, 2018; Krishnamurthy *et al.*, 2014; Koutroulis *et al.*, 2018).

Thereby, this paper aims to contribute to assess the climate change impact, proposing the Iyengar and Sudarshan's Method, as the appropriated method to determinate the weight of each climate vulnerability indicators.

MATERIALS AND METHODS

Materials

In this paper, we used the data of the Barigui river basin in Curitiba-Paraná (Table 02). It was collected 81 data which compose an 11 years time-series. Were collected data from the national institutions such as Secretary of State for the Environment and Water Resources, and also the State Coordination of Protection and Civil Defense of Parana.

Table 02 – Data of the Barigui river basin.

Component	N.	Data 1	Data 2	Data 3	Average
Exposure	E1	2.20	2.00	0.77	1.66
	E2	0.00	0.00	0.00	0.00
	E3	3.27	2.17	1.08	2.17
Sensitivity	S1	50.00	50.00	50.00	50.00
	S2	5,145.93	416.67	7,730.77	4,431.12
	S3	31,058.80	1,336.50	225.15	10,873.48
Adaptive Capacity	AC1	0.33	0.42	0.38	0.38
	AC2	0.73	0.92	0.85	0.83
	AC3	0.73	0.92	0.85	0.83
Governance	G1	0.93	1.17	1.08	1.06
	G2	1.33	1.67	1.54	1.51
	G3	0.27	0.33	0.31	0.30

Methods

The weight Determination (equation 01), is based on the principle that weight is defined by uncertainty aggregate on variance, meaning that as the greater the variance is, the smaller the weight will be (Iyengar and Sudarshan, 1982).

$$W_i = \frac{NC}{\sqrt{var(X_i)}} \; ; \left(0 < W_i < 1 \;\; and \; \sum_{i=1}^{n} W_i = 1\right) \qquad (01)$$

where W_i is the weight, X_i is the normalized score, n (i = 1, 2, …, n) indicators of main goal, and NC is a normalizing constant, determined by (equation 02):

$$NC = \left[\sum_{i=1}^{i=n} \frac{1}{\sqrt{var(X_i)}}\right]^{-1} \qquad (02)$$

However, it is very important to know the relationship between the indicator and main goal to ensure that the indicator values are always in positive correlation with the main goal (Kumar *et al.*, 2017). Therefore, before using the data to determinate the weight, they have to be normalized to put on the dimensionless way and allow comparisons between them (Anandhi and Kannan, 2018). It means, we recommend applying the equation (03) when the indicator increase and the main goal also increase Pandey and Jha, (2012), and apply the equation (04), when the indicator increase and the main goal also decrease (Pandey et al., 2017).

$$X = \frac{X_v - X_{min}}{X_{max} - X_{min}} \qquad (03)$$

$$Y = \frac{X_{max} - X_v}{X_{max} - X_{min}} \qquad (04)$$

where X_v is the value to be normalized, X_{min} and X_{max} are the minima and maximum values of the indicator on the impact area, X and Y are the normalized values.

RESULTS

According to the principle of the uncertainty on variance Iyengar and Sudarshan, (1982), we determinate the weight of each indicator (Table 03).

Table 03 - Weight determination of each indicator.

INDICATOR	VAR	SQRT VAR	1/SQRT VAR	NC	WEIGHT
E1	0.293	0.542	1.847	0.043	0.0793
E2	0.295	0.543	1.842	0.043	0.0790
E3	0.250	0.500	2.000	0.043	0.0858
S1	0.254	0.504	1.982	0.043	0.0851
S2	0.257	0.507	1.972	0.043	0.0846
S3	0.322	0.567	1.763	0.043	0.0757
AC1	0.254	0.504	1.983	0.043	0.0851
AC2	0.254	0.504	1.983	0.043	0.0851
AC3	0.254	0.504	1.983	0.043	0.0851
G1	0.254	0.504	1.983	0.043	0.0851
G2	0.254	0.504	1.982	0.043	0.0851
G3	0.254	0.504	1.982	0.043	0.0851

With these results and using the same approach as for indicators, were defined the weight of each component (Table 04).

Table 04 – Weight determination of each component.

COMPONENT	VAR	SQRT VAR	1/SQRT VAR	NC	WEIGHT
E	0.003	0.051	19.621	0.004	0.0801
S	0.000	0.018	54.204	0.004	0.2213
AC	0.000	0.008	118.949	0.004	0.4857
G	0.000	0.019	52.123	0.004	0.2128

The adjustments on the system through the Adaptive Capacity has the highest value (0.4857), compared with the Governance (0.2128), and Sensitivity (0.2213), representing the magnitude of the impact on the system. Exposure (0.1473) has the lowest value, supposing less confidence in the data due to the significance of the dispersion measure, resulting from the quality of data, mainly the gaps such as having 0.0 for no data in five consecutive years and 1,750 or more in the next years.

DISCUSSION AND FINAL CONSIDERATION

This paper aims to propose the Iyengar and Sudarshan's Method, as the appropriated method to determinate the weight of each climate vulnerability indicators and avoid the subjectivity of weight determination. The results show that using this method the variation of one indicator does not interfere incorrectly in the contribution of the remaining indicators, as proposed by Iyengar and Sudarshan, (1982), adopted by Pandey and Jha, (2012), suggested by Mazziotta and Pareto, (2013) and many others, on the previous discussions. Therefore, the Iyengar and Sudarshan's Method showed as a very acceptable and helpful tool to deal with subjectivity mainly if we take into account the difference on the impact of each component in the system, and the quality of available data. However, it is very important to pay attention to the gaps in data. Otherwise, the process will be based on a strong conceptual framework and led by expertise and decision-makers to be widely accepted, which used to be very questionable due to the controversial subjectivity of the judgments.

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