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ANALYSIS OF LANDSCAPE CHANGE: A NUMERICAL APPROACH IN A STUDY OF CASE IN THE POLISH CITY OF TORUŃ*

ANÁLISE DE MUDANÇA DA PAISAGEM: UMA ABORDAGEM NUMÉRICA EM UM ESTUDO DE CASO NA CIDADE DE TORUŃ

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ABSTRACT

This paper analyzes the relationship between a natural landscape and extreme natural phenomenon, having as the study area the neighbourhood Kaszczorek in the Vistula river valley of Toruń, Poland. The methodology combined a literature review, fieldwork in Poland and data analysis of the information obtained by applying the theory Shannon and Weaver theory in order to applied to measure the relationships between natural landscape and extreme natural phenomenon and establish combinations between some variables of the landscape. The result obtained is 9.2% of change at in the natural landscape.

Keywords: Landscape, floods, climate change, risks, hazards, Toruń.

RESUMO

Este artigo analisa a relação entre a paisagem natural e fenómeno natural extremo, tendo como a área de estudo o bairro de Kaszczorek no vale do rio Vistula em Toruń, Polónia. A metodologia combinou uma revisão da literatura, o trabalho de campo na Polónia e a análise de dados das informações obtidas através da aplicação da teoria de Shannon e Weaver aplicada para medir as relações entre paisagem natural e fenômeno natural extremo e estabelecer combinações entre algumas variáveis da paisagem. O resultado obtido é de 9,2 % de variação na paisagem natural.

Palavras-chave: Paisagem, inundações, mudanças climáticas, riscos, perigos, Toruń.

Introduction

Geographical research related with numerical analysis of landscape change using photography is useful for contribute to better understand how extreme natural events affects different elements of landscape. The field of ecology of landscape (science of studying and improving relationships between ecological processes in the environment and particular ecosystems) and geographical perception can improve the information about landscape change as result of climate events. In some cases, the speed of the changes of landscape in society that makes many details goes unnoticed in as result of the urban dynamics.

It is important better understand the relationship between the human population and their environment, the human population is the primary cause of the environmental changes nowadays. Many environment effects are caused locally, although the same patterns are repeated across the world. It is important the explore knowledge that need to be harnessed for a sustainable society and applied in ecological situations (C. R. Townsend, 2008).

The frequency of elements in the landscape, when an item type more extensive than others, can be considered a relative area of the landscape. The most extensive normally controls the flow of the landscape. The structures are determinants by human influence (R. T. T. Forman & M. Gordon, 1986).

Natural risks are a public safety issue that requires appropriate mitigation measures and means to protect citizens, property, infrastructure and the built cultural heritage. Mitigating this risk requires integrated and coordinated action that embraces a wide range of organizations and disciplines. Adaptation to climate change was slow to emerge into the international climate scene. Today, however, receives growing attention at all levels.

Some details enable a reading of human action on the landscape, which can interfere in the community (e.g. dam barrage that impounds water or the change of the natural course of a river). This type of study is inserted in Cultural and Geographical theory of perception, by the comparative method (former and using current photograph).

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The images represent fragments of historical moments, cultural, social possibility to monitoring the changes in the landscape.

Poland is not a country very affected by climate impacts at the Eastern Europe (S. Kreft & D. Eckstein, 2013). The analysis of the occurrence of natural disasters in Poland during 1985 and 2014 indicates that the main hazards are: extreme temperature (cold wave and extreme winter conditions), flood, storm and wildfire. The analysis of the biggest 10 natural disasters in Poland, sorted by numbers of total affected people (1985-2014), indicates that the events were floods and storm. The main flood occurred in July 1997 (affecting 224,500 people) and the main storm occurred in March 2008 (affecting 1,060 people) (Em-dat).

The research was made with the case study of the historical flood in 2010 in the city of Toruń, Poland; the study was based on empirical research and observation. The field research had been made in Toruń in September 2013. The suffered flooding areas were the main part of the investigation was the photos taken in order to collect data regarding the landscape change.

Study area and methods

The study area is the view of landscape of the neighborhood Kaszczorek in the city of Toruń on the Vistula River. The city of Toruń is situated between 52°58’ and 53°04’ of north latitude, between 18°32’ and 18°43’ of east longitude, the city covers the area of 115 km² (E. Adamska, 2011). Is listed on the UNESCO list of *World Heritage Sites* since 1997. Toruń has many monuments of architecture beginning from the middle ages. The city is famous for having preserved almost intact its medieval spatial layout and many Gothic buildings.

The city of Toruń is located in central Polish lowlands, in the province of Wojewodztwo, on the banks of the River Vistula. The town has 188,991 inhabitants (Web of the city of Toruń, 2014). The old medieval city centre borders the north bank of the river. It is situated in the region of the Toruń valley, the Vistula it is the biggest river in the Baltic Sea catchment area, with the best retained natural characteristics in its middle stretch through the Mid-Polish lowlands. The study area in this article can be seen on the fig. 1 with the map. More importantly, the Vistula is also one of the biggest European River, where it allowed to meander more or less undisturbed between winter dikes.

The Vistula River basin forms an important ecological corridor for animal and plants connecting southern and north parts of Central Europe Lowlands. The Vistula floodplains with its meanders, islands are also a specific habitat for many aquatic and terrestrial species.

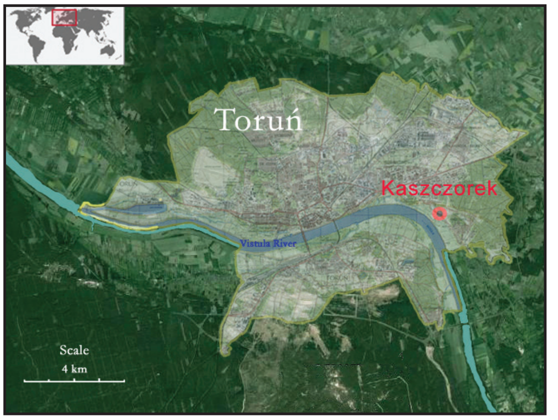

Fig. 1 - The location the neighbourhood Kaszczorek in Toruń and Vistula River in Poland.

Fig. 1 *- Localização do bairro de Kaszczorek em Toruń e Rio Vistula na Polónia.*

The majority of data are from the authors field work carried out in 2010 and 2013. The method used for the landscape analyze it had used tools of geographical information system, for the analyses of the landscape. In this research the network analysis of the areas, the numbers of pixels were count of each element considered to determine the coefficients applied using the theory of information of Shannon information theory and Weaver (1943).

Methodology and landscape classification

It is considered part of the landscape (E), any component of the landscape we can distinguish only the sensitivity of the human eye. The same component can cause many items if they are disjoint or colours different.

It is considered part of the landscape (E), any component of the landscape we can distinguish only the sensitivity of the human eye. The same component can be vary due to the disjoint or various colours, such as a pasture or a crop that is discoloured clearly different due to topography. As an example development has taken a landscape image of Vistula Valley River, where the remnants of natural vegetation elements are intermingled with agricultural vegetation.

This combination generates a set of landscape typologies defined by shapes of the tree, for different types of crops. Sets of colours occurs, highlighting the contrast of vegetation greenness tree with other hues grassland and upland crops (F. R . Pallarés & J. M. R. Mellado, 2008).

The landscape elements of human evaluation have distinguished aspects concerning colour, shape and density of the vegetation as well as the positioning with respect to observer. Part of the image is formed by other elements such as the sky small buildings. Landscape elements considered are shown in the Table I.

Table I - Elements of the landscape analyzed in the fig. 1 and fig. 2.

Tabela I - Elementos da paisagem analisados na fig. 1 e fig. 2.

n	Elements
1	Vegetation, first line
2	Tree
3	Vegetation, second line
4	Vegetation, second line after the river
5	Water (the Vistula River)
6	Vegetation, third line
7	Grass
8	Sky

Data acquisition

The impact of flooding on the landscape is very complex and varies according to the rainfall pattern and scale of observation. The spatial organization of the landscape mosaic, within which variables interact, are studied to measure these relationships. To establish combinations between the variables and landscape change, the Shannon information theory and Weawer (1943) provides concepts and methods in generated original quantitative data., the landscape can be seen as a flow of information between a defined set of messages from not biotic and biotic descriptors the middle (F. Burel & J. Baudry, 2002). The basis of the formalism is the Shannon formula is expressed by the equation 1 below:

$$H = -\Sigma(p_i*logp_i) \qquad \text{(Equation 1)}$$

Where n is the number of possible outcomes and pi is the probability of occurrence of outcome *i* (1,n). Each element occupies a surface (S) of the image, which corresponds with a proportion of the total area of surface of image (S). Landscape value is called by its elements the result of applying the Shannon-Weber theory. The measure the diversity of elements that make up the landscape (V), can be expressed by the equation 2:

$$V = -S_i*p_i*log_2*p_i \qquad \text{(Equation 2)}$$

When performing any act amending elements of the landscape, both the type of items as quantity. It can be defined landscape impact index (IPP) as the equation 3:

$$IPP = (V'-V_e)/V_e \qquad \text{(Equation 3)}$$

Where *V´* is the value of the landscape for their items before acting and V_e is the value of the landscape for their items after the flood. It is possible a positive, zero, or negative result. For the analysis proposed in this paper, it is considered that the image landscape is likened to a photographic image. The fig. 2 and fig. 3 show the photographic image of the landscape with different considered landscape elements delimited by lines with different colours.

The surface of landscape was divided by colourful lines that correspond to the elements present in the landscape. When performing any act amending elements of the landscape, both the type of items as its quantity, and the proportion in which each element is in the landscape. Any action on the natural environment can increase diversity as it introduces one or more new elements in the landscape. Not however, one must perform reasoning from the point of view global modification generates action on the landscape. In the first case there is an irreversible modification of the landscape; in the second case the loss can be offset by measures to correct the action.

A numerical objective analysis of these two types of modifications is essential for developing preventive and corrective measures that minimize landscape impacts and understand better natural extreme events.

The flooded area is subtracted from the surfaces of the landscape elements that directly affected it. The landscape element in one situation may disappear if the action passes directly overhead, other elements will have less surface according to the amount of action that affects, the ratio “pi” these elements according with the theory of Weawer (1943) will be smaller.

It had been applied in the landscape of the Vistula river valley, comparing two situations: one with the valley of the Vistula river flood in 2010 and other without flood in 2013. The analysed photograph from 2013 were taken more or less at the same spot as the one from 2010.

When performing an act amending elements of the landscape, than element (n) and size can change. It can be defined landscape impact index (IPP). Where *V´* is the value of the landscape for their items before acting and V_e is the value of the landscape for their items after the flood. The results can have a positive, zero, or negative.

The analysis of the Table II and Table III contain the calculations with the concepts of the information theory of Shannon and Weawer (1943) presented. In the Table III below, the yellow boxes indicate natural information loss; the orange box indicates introducing elements.

It is observed that there are eight landscape elements that are affected in greater or lesser extent by the presence of the flood, the surface decreases their part and decreases the product. The more precisely analysis of how each element change had changed comparing the two different situations, indicates the grass on the first line (n=1) suffered an change of 15 per cent, while the tree (n=2) suffered an change of 12 per cent , the vegetation on the second line (n=3) suffered an change of 57 per cent, the vegetation on the second line after the river (n=4) suffered an change of 68 per cent, the water on the Vistula river (n=5) suffered an change of 97 per cent, the vegetation on the third line (n=6) suffered an change of 71 per cent, the grass (n=7) suffered an change of 100 per cent and the sky (n=8) suffered an change of 31 per cent. The practical effects on the landscape were most observed on the river and on the grass that was replaced by water.

The value obtained is -0.0916 (IPP), it can be interpreted as change of 9.2% of natural landscape. After analyse the difference of pixels, unit of size compared in each element of the landscape of the two images, the

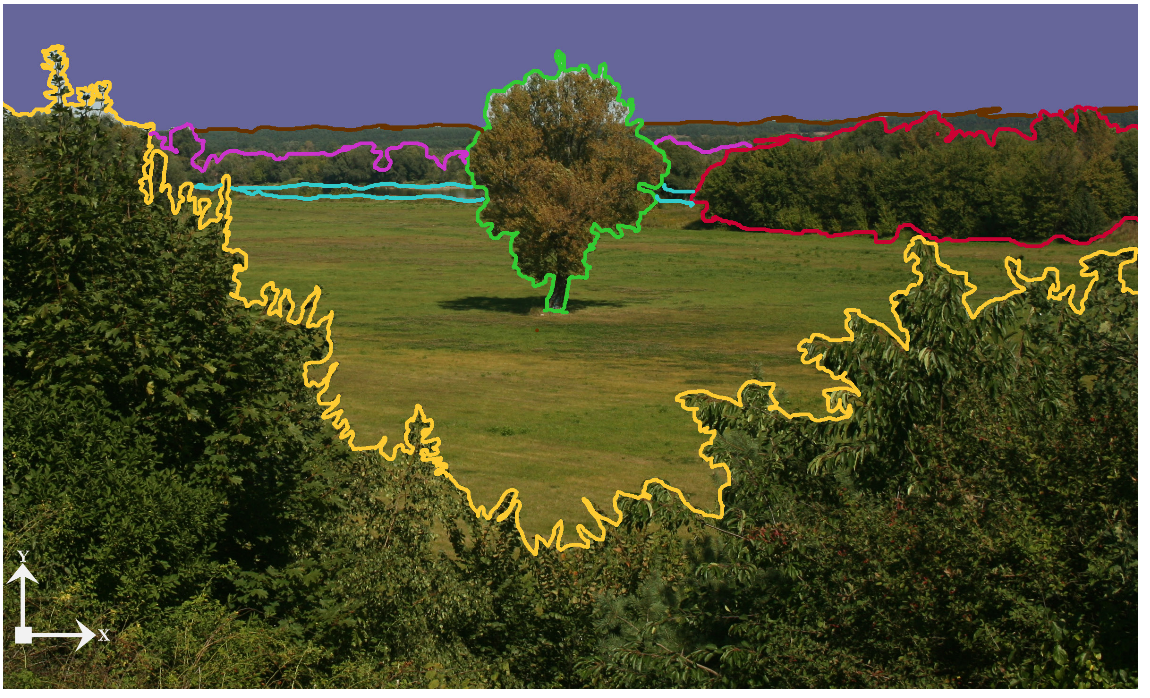

Fig. 2 - Landscape the neighbourhood Kaszczorek in Toruń in 2013 (Photograph: Rodrigo R. R. Ribeiro).

***Fig. 2** - Paisagem do bairro de Kaszczorek em Toruń em 2013 (Foto: Rodrigo R. R. Ribeiro).*

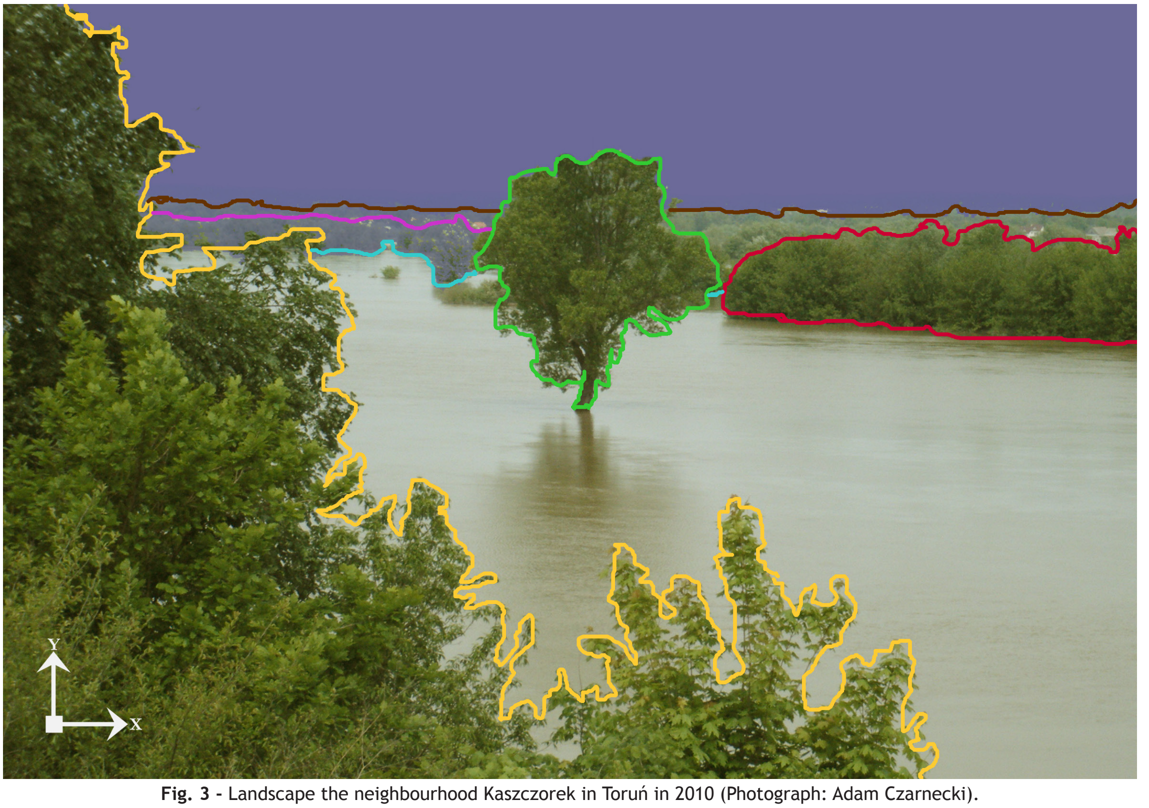

Fig. 3 - Landscape the neighbourhood Kaszczorek in Toruń in 2010 (Photograph: Adam Czarnecki).

***Fig. 3** - Paisagem do bairro de Kaszczorek em Toruń em 2010 (Foto: Adam Czarnecki).*

landscape value and the error (E) is ±0.13 considered. This loss of value corresponds to the chosen lookout; it may exist more point's observation in which there will be no loss of landscape value, or in which there is a greater loss.

Conclusions

The proposed method is a numerical analysis of the landscape and provides a good tool for analyze the impact of some extreme natural phenomenon. This numerical analysis is a novel methodology in the field of impact studies regarding cases of floods. The concepts defined landscape value for their items and Index landscape impact allow objective quantification of the landscape without and with action. The approach in this research is not about the infrastructure surrounding landscape looks, but how it had changed.

The picture with the flooded area allows the analysis of landscape value with and without floods. The obtained result is 9.2% of change at the natural landscape and can be understood as the effect of the phenomenon that in this case is a flood.

It is necessary define different observation points for infrastructure proposal to allow a thorough analysis of all possible impacts landscape. The fieldwork is laborious but not difficult. It is very important to have a painstaking fieldwork that allows selecting on-site most appropriate viewpoints.

Table II - Numerical analysis of landscape without flood in the year of 2013 (made by the author).

Tabela II - Análise numérica da paisagem sem inundação no ano de 2013 (elaborado pelo autor).

			Without flood (2013)			
n	Elements	S_i (Surfaces)	p_i	log (p_i)	(S_i)*log(p_i)	S_i*p_i*log p_i
1	Vegetation, first line	22,8	0,515419	-0,956181	0,492834	0,254016
2	Tree	22,8	0,033750	-4,888957	0,165004	0,005569
3	Vegetation, second line	22,8	0,042808	-4,545981	0,194604	0,008331
4	Vegetation, second line after the river	22,8	0,019786	-5,659340	0,111979	0,002216
5	Water (Vistula River)	22,8	0,029653	-5,075688	0,150508	0,004463
6	Vegetation, third line	22,8	0,015689	-5,994101	0,094042	0,001475
7	Grass	22,8	0,173064	-2,530618	0,437960	0,075795
8	Sky	22,8	0,169830	-2,557840	0,434397	0,073773
			Value of Landscape (1)			**0,425639**

Table III - Numerical analysis of landscape during a flood in the year of 2010 (made by the author).

Tabela III - Análise numérica da paisagem durante uma inundação no ano de 2010 (elaborado pelo autor).

			With flood (2010)			
n	Elements	S_i (Surfaces)	p_i	log (p_i)	(S_i)*log(p_i)	S_i*p_i*log p_i
1	Vegetation, first line	22,8	0,422759	-1,242093	0,525106	0,221993179
2	Tree	22,8	0,036483	-4,776616	0,174267	0,006357858
3	Vegetation, second line	22,8	0,032840	-4,928414	0,161848	0,005315036
4	Vegetation, second line after the river	22,8	0,014715	-6,086587	0,089563	0,001317903
5	Water (Vistula River)	22,8	0,319522	-1,646014	0,525937	0,168048336
6	Vegetation, third line	22,8	0,032139	-4,959530	0,159394	0,005122781
7	Grass	22,8	0	0	0	0
8	Sky	22,8	0,141542	-2,820693	0,399248	0,056510539
			Value of Landscape (2)			**0,464665631**

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