Comparative Analysis of urban efficiency in medium-sized cities through Hidricidade indicators

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ABSTRACT: Urban expansion and the strategies of planning policies in the urban area of the city are in conflict, so disjointed as they occur without practical tools for decision-making on the part of public managers. The traditional model is characterized by expansive growth that promotes a more costly and less efficient city. The Hidricidade indicators focused on efficiency urban are tools for assessing the growth of cities based on their water balance. The purpose of this article is to make a comparative analysis of the application of these indicators in some medium-sized cities in order to test the method and conclusions on urban expansion strategies evaluated in each city. The results show that medium-sized cities analyzed grow unsustainably, specifying revise their expansion strategies and monitor this growth, since by its size still have reversibility conditions.

Keywords *Hidricidade Indicators –Urban Efficiency –Urban Sprawl – Water –Urban form.*

ISBN: 978-85-92631-00-0

1. INTRODUCTION

The economic development of recent years has been characterized by inadvertent exploitation of natural resources occasioning environmental degradation and climate change felt in many parts of the world. Such attitudes result in serious and irreversible consequences for future development. Therefore, concern is increasing among public managers where plans and initiatives must approach sustainable criteria and propose improvements in services of the city (Berardi 2013). According to the document Panorama of Cities and Biodiversity, the world population by 2050 will reach 9 billion, and 70% of them live in cities. Until then, with profound changes in land use processes, water, energy and other natural resources, the planet has suffered the largest and most rapid urban expansion of humanity, an irreversible trend of transformation to a predominantly urban world.

The planning of cities is a challenge increasingly vast and complex as it needs to suit the demands of the built city and new urban expansions without losing focus on balance with the ecosystem needs, landscape and natural processes, such as the urban water cycle. Urban spaces can be developed in order to maximize opportunities offered by the natural environment. That is important to focus attention to the extraordinary richness of urban biodiversity and its role in generating environmental services which populations depend for food, water and health. This means it is necessary to integrate the field of natural sciences to the field of humanities and social sciences in the context of urbanism, in which fits the connection between ecology and urban design (Andrade 2014).

However, there is still a tendency in the planning of cities to ignore the natural processes, an inability to realize opportunities, especially in the interactions between human activities and urban form, with natural processes. All essential chemical elements to life tend to circulate in the atmosphere in more or less cyclical characteristic ways, ranging model environment for the body and back to the atmosphere, known as biogeochemical cycles, such as the water cycle (Odum & Barrett 2007). Many scientific advances have been made on sectorial aspects of biodiversity, such as water resources, soils, biomes, etc. However, minors were the advances of research on the processes that structure and involving more variables, such as urban water cycles.

Similarly, there is little research that addresses usage patterns and land use in urban settlements and building forms adapted to the processes that shape the natural resources, such as the paths of water in the hydrological cycle, for example. When cities designs make "visible" these processes and their temporal cycles contribute to the connection between the past and even the future of uncertainty and in a way, for rooting people in place (Spirn 2011).

According to the report of the Worldwatch Institute, State of the World 2013 (WWI 2013) it is necessary to establish a planetary boundary for freshwater resources to ensure that their flows to regenerate in the form of precipitation sustaining terrestrial ecosystems and ensure the availability of water to aquatic ecosystems.

Multidisciplinarity has been sought for the decision making regarding urban design, driven by documents produced by international organizations, the possibility of mitigating environmental impacts, especially from the perspective of the urban water cycle. In many

ISBN: 978-85-92631-00-0

parts of the developed world, designers and planners began to experiment these possibilities with new urban design standards and through some of his experiments, developed a body of knowledge about the possibilities of the cities are built and adapted to work differently (Hill 2009). As the urban population will continue to increase and putting more pressure on natural systems, planning and projects should be more comprehensive, being forced to take into account the complex interactions of natural processes in urban systems. For French (2014), when addressing the design and urban infrastructure management in a more holistic way, that can take advantage of the synergies that exist between the natural and the built environment creating more sustainable infrastructure solutions. To create infrastructure systems operating within resources and assimilative capacity that nature provides, one must consider the infrastructure systems holistically and identify where the inputs and outputs of each system are likely to impact the other system.

Therefore, to promote the urban development sensitive to water, it required an understanding of hydrological processes, the use and occupation of the soil, associated infrastructure, public management and other processes and associated variables. We must understand the real limits and support capability related to the use of urban land. Urban growth should adapt to the sustainability requirements in order to ensure the survival of future generations. Thus, it is necessary to identify variables that allow understand these processes and link them so that it is possible to obtain a diagnosis. From this, it is possible to define strategies and intervention measures, allowing to predict future scenarios and to guide preventive actions.

In order to assess the changes to improve urban performance indicator sets, frameworks and assessment tools have been developed. Urban sustainability indicators are crucial to assist in goal setting, performance evaluations and facilitate communication between social and urban managers (Brandon & Lombardi 2011).

This article presents eight "Hidricidade" indicators, which assess issues related to urban efficiency in medium-sized cities. The word "Hidricidade" is a Portuguese acronym created for adjectives the variables of the research, i.e., involves aspects of water resources (Hidro), city (cidade) and sustainability (sustentabilidade).

A comparison of the application of the methodology will be presented between the cities of Caxias do Sul in Brazil and Cuenca in Ecuador. These cities were chosen because they have similar characteristics both represent joint centers in their regions and in water management to be municipal responsibility, are Latin American cities that have a strong management evolved regarding water management. According Cimes (1999) averages cities articulate the territory and serve as reference centers for a territory, more or less immediately.

2. INDICATORS

Despite the apparent popularity of using sustainable development indicators, its definition remains very general; however, the absence of a less general definition for universal sustainable development originated various interpretations and a large number of types of indicators (Tanguay et al. 2010).

ISBN: 978-85-92631-00-0

The city lacks indicators to transversal analysis, as well as describing the assessment of the city in areas such as water management and its territory. Based on this, this research was used eight indicators that aim to measure the Urban Efficiency. Overall, these indicators seek quantify aspects concerning the operation of the city, especially in terms of water management and urban use, as can be seen in the list presented in Table 1. From the calculation of these indicators, using two case studies, it is to analyze how land use, distribution of residences and people with consequent urban sprawl relate to sanitation infrastructure, i.e., the use water in its urban cycle.

The calculation process of each indicator was developed from literature review that allowed compiling a series of indicators that associate the proposed variables, deciding criteria that would allow prioritizing the definition of the following indicators: population density (Dpop) is the most frequent in the literature and its application is very common; Residential density (Dres) aims to quantify the ratio of the number of homes and land area, from which it is possible to analyze the efficiency of urban functions in the attendance of the population. Water network extension by connection (Iexa), extension water network by land area (Iextr) and extension of the sewage network by connections (Iexe) are indicators that measure the distribution infrastructure in the territory; i.e., the density of water and sewer pipes associated with the public service provided to the population. The indicator numbers of economies by land area (Iecot) represent the number - quantity - water collection accounts by land area. The indicator soil sealing (Iimp) is a measure of the ratio between the sealed soil area and land area, allowing analysis of the constructed space.

Table 1. "Hidricidade" Indicators – Group Urban Efficiency. Source: Own elaboration

Group	Identifier	Indicator	Initials	Unit
Urban Efficiency	I-1	Population density	*Dpop*	hab/ha
	I-2	Residential density	*Dres*	resid/ha
	I-3	Urban spot design	*Iforma*	%
	I-4	Water network extension by connection*	*Iexa*	m/ligação
	I-5	Extension water network by land area	*Iextr*	m/ha
	I-6	Number of economies by land area**	*Iecot*	econ/ha
	I-7	Extension of the sewage network by connections	*Iexe*	m/ligação
	I-8	Soil sealing	*Iimp*	%

* When it comes to water connections are referring to any link between the main water supply to the land where the building is. A ground whose construction is a multi-family building has only one connecting water or sewage.

**When it comes to economy it is referring to all land- use units. A residence, a commercial, an industry, each of these is an economy.

These indicators are intuitive to use, the opposite to the design of urban sprawl (Iforma), which was the target of a wide range of analysis and studies; the aim being to evaluate the shape of the urban sprawl and growth trends. Restlessness that cities cannot move indefinitely on its natural environment has been a constant during this search. To derive the equation computation of the indicator, it was necessary real case studies that, by observing its urban development, have created an expression for its calculation.

ISBN: 978-85-92631-00-0

2.1 Benchmarking and evaluation through abacuses

Before calculating the indicators for each city object of this research, it is necessary to find parameters, also known as best practices and standard practices (benchmarking), to allow comparison of results giving subsidies to the decision-making process regarding the urban management (Matthew & Braganza 2009). It is considered best practice great goal that a municipality could reach or exceed to be considered effective as the indicator in question. The conventional practice is the minimum level that regulations, standards and laws should contain as limits on the measured aspects. Table 2 presents the values for best practices and conventional practices used in this process on the urban efficiency indicators (Ulian 2015).

Table 2. Values adopted for Best practice and Conventional practice
Source: Own elaboration.

Group	Identifier	Initials	Unit	Best practice	Conventional practice
Urban Efficiency	I-1	*Dpop*	hab/ha	135	43
	I-2	*Dres*	resid/ha	85	14
	I-3	*Iforma*	%	70	37
	I-4	*Iexa*	m/ligação	9.4	20.5
	I-5	*Iextr*	m/ha	158.7	139.7
	I-6	*Iecot*	econ/ha	51.6	17.2
	I-7	*Iexe*	m/ligação	9.4	15.4
	I-8	*Iimp*	%	70	50

The benchmarking was obtained by analyzing the SNIS database (Information System on Sanitation) administered by the Brazilian federal government. When it was not possible to obtain information on Brazilian cities were also sought data on foreign cities of recognized environmental management.

The comparison between the obtained indicators and benchmarks becomes complex as it is necessary to simultaneously impart eight numeric values, for which is used the representation of indicators according abacus, similarly to what can be done in the definition of scenarios concerning water management (Gallopin 2012); taking to the evaluation process an abacus that has all of the proposed indicators of urban efficiency, there is no need to standardize the scales, although this could be done. From this abacus it is possible to draw conclusions, visually. Figure 1 shows the corresponding abacus the benchmarks, which should be compared with the abacus city to be evaluated.

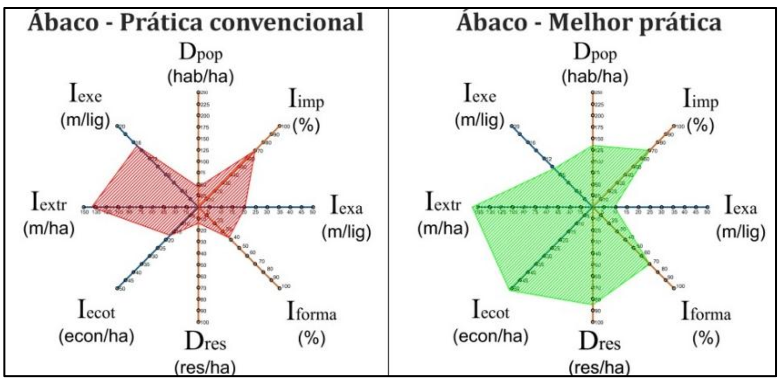

Figure 1. Abaci benchmarking for best practice and conventional practice.
Source: Own elaboration.

ISBN: 978-85-92631-00-0

3. ASSESSMENT OF DIAGNOSTIC APPLICATION OF URBAN EFFICIENCY IN CAXIAS DO SUL AND CUENCA

3.1 Presentation of Caxias do Sul, Brazil

Caxias do Sul is located in the northeast region of Rio Grande do Sul state in southern Brazil being the second largest city in the state. It has a population of 435,482 inhabitants, of which only 3.7% live in rural areas (IBGE 2010). With a land area of 1,644 square kilometers, has only 744 square kilometers (45%) belong to the rural area. It is located in two river basins, 53% in the basin of the Taquari and Antas rivers and 47% in Caí River basin, as presented in Figure 2. It has an average elevation of 780 meters and average rainfall of 2,000 mm / year. In 1963, initiated the use of studies of the new source, the Maestra stream. Other systems were developed later: Dalbo, Faxinal, and more recently Marrecas. Currently all these systems are in operation. There are studies to two sources, the streams of and Piaí and Sepultura, all further away from the urban area. The Caxias do Sul water is obtained 98% of surface, made by damming streams in small flow.

3.2 Presentation of Cuenca, Ecuador

Cuenca is located in the southeastern region of Azuay Province, southern Ecuador being the third largest city in the country. It has a population of 505,585 inhabitants, 329,928 of these are in urban areas. It has an area of 66.71 square kilometers with altitude ranging between 2,350 and 2,550 meters. The water supply from Cuenca comes to El Cajas National Park, located at an altitude between 3,152 and 4,445 meters, with annual rainfall 1,000-2,000 mm per year. Of total rainfall, it is estimated that 64% returns to the atmosphere by evapotranspiration and only 36% supporting ecosystems. Of these 36% about 35% are used for human needs. The hydrological network in the urban area consists of four river basins: the Tomebamba, Machángara, Yanuncay and Tarqui, according to Figure 3. All have steep slopes and small concentration of times, increasing risks of flooding in the lower parts of city. These features are common in places with interference of the Andes formation (Godoy 2016).

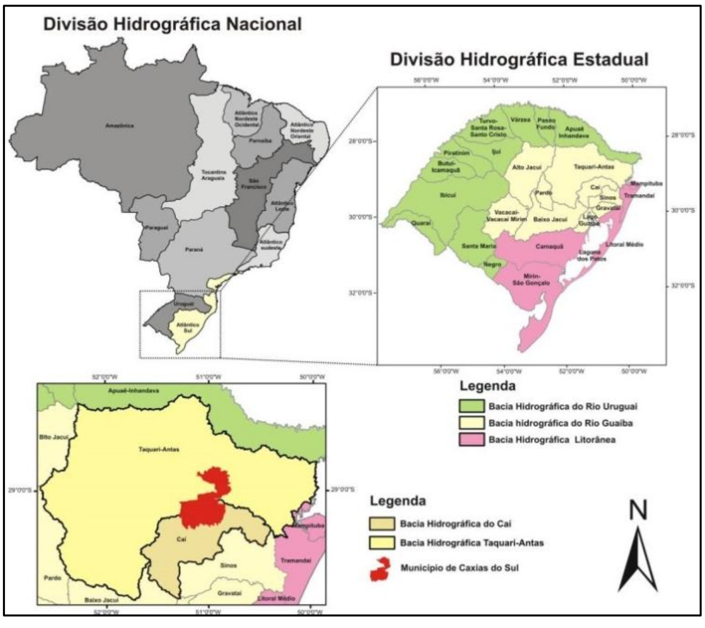

Figure 2. Location of Caxias do Sul in national land local hydrographic divisions.
Source: Own elaboration.

ISBN: 978-85-92631-00-0

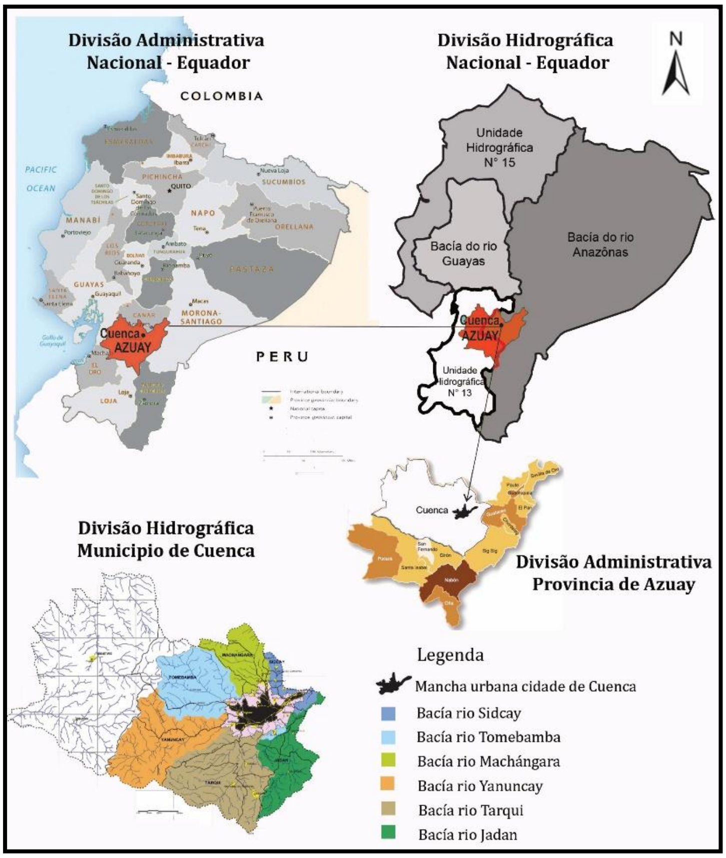

Figure 3. Location of Cuenca – Ecuador, in national land local hydrographic divisions.
Source: Own elaboration based on Godoy (2016).

3.3 Analysis and discussion of results

Calculate indicators for two similar cities allowed an assessment of the method and also analyze not converging aspects of cities. The creation of indicator systems is estimated that some trends are obvious, but the observation demonstrates the contrary. Were calculated indicators for Caxias do Sul and Cuenca, according to that shown in Table 3.

Table 3. Calculation of Urban Efficiency Indicators Caxias do Sul/Brazil – Cuenca/ Ecuador.
Source: Own elaboration.

Group	Identifier	Initials	Unit	Calculated values	
				Caxias Do Sul	Cuenca
	I-1	*Dpop*	hab/ha	46.08	36.01
	I-2	*Dres*	resid/ha	22.6	9.42
	I-3	*Iforma*	%	35.91	21.94
Urban Efficiency	I-4	*Iexa*	m/ligação	12.11	10.66
	I-5	*Iextr*	m/ha	173.15	129.11
	I-6	*Iecot*	econ/ha	20.74	13.07
	I-7	*Iexe*	m/ligação	14.24	11.63
	I-8	*Iimp*	%	50	68.2

The indicator population density for Caxias do Sul is equal to 46.08 inhabitants / ha, lying much closer to the conventional practice (43 inhabitants / ha) than the best practice (135 inhabitants / ha). In Cuenca the calculated indicator is further below with conventional practice a value of 36.01 hab / ha. The indicator for the residential density presents a

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similar result, with 22.6 resid / ha to Caxias do Sul - close to the conventional - and 9.42 resid / ha to Cuenca - below the conventional practice. Figure 4 shows the result of applying indicators in the form of abacus. It can be concluded that urban expansion of Caxias do Sul and Cuenca should also seek to increase their densities, before promoting new urban expansions, which correspond to the approach of their abacuses to best practices. To aggregate and qualify this conclusion, it is also noted the design of urban sprawl both cases studied in comparison with the circular form of the originally proposed model.

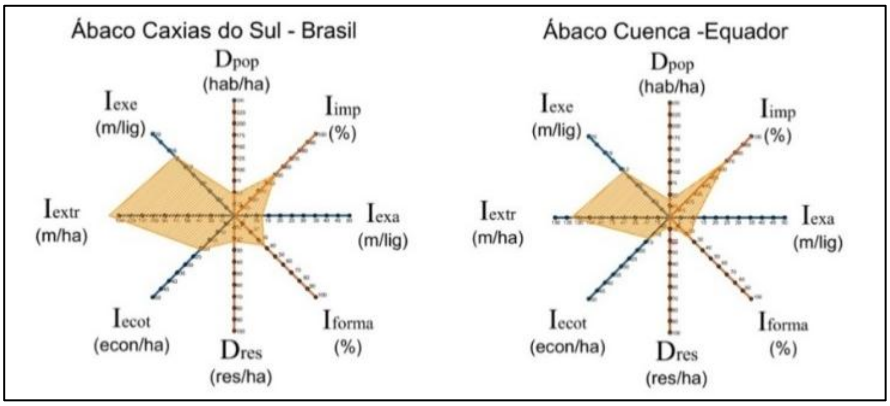

Figure 4. Benchmarking Abacuses with Efficiency indicators for Caxias do Sul – Brazil and Cuenca – Ecuador. Source: Own elaboration.

Figure 5 shows the images used to calculate the index form, referring to the urban area of Caxias do Sul and Cuenca. The best practice for *Iforma* is 70% while for Caxias do Sul this index was calculated at 36% and even worse for Cuenca, with 22%. Additionally, analyzing Figure 5 is possible to conclude that Caxias do Sul has a footprint out of the circular shape equal to 37% of its total area (Amancha), while Cuenca is 34%. This result confirms the conclusions drawn from the first indicators already analyzed.

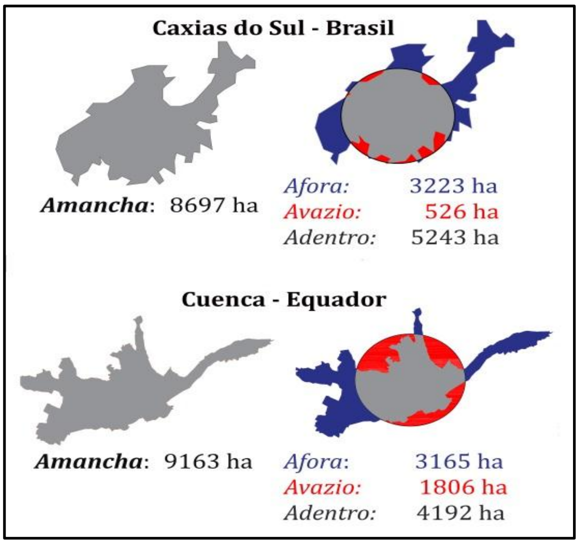

Figure 5. Application of *Iforma* Indicator in Caxias do Sul – Brasil and Cuenca – Ecuador. Source: Own elaboration.

The indicators relating to the distribution of basic sanitation infrastructure show minor discrepancies with respect to the reference: The *lexa* shows up best in Cuenca than Caxias do Sul, where it gets more people with less piping. The *Iextr* measures the density of pipes

ISBN: 978-85-92631-00-0

in the territory, where Caxias do Sul has a much better result than Cuenca, the latter with values even below the conventional practice. The *Iecot* presents many economies occur in the territory where the results for both cities are unfavorable, with Caxias do Sul just above the conventional practice and Cuenca below this, demonstrating once again the need to increase density. The *Iexe* and *lexa* indicators show how many people are served per meter pipe for sewer, where both values were superior to the conventional practice, with Caxias do Sul closer to best practice than Cuenca. These indicators together show that the infrastructure relating to the definitions could be better planned, so that more people could be served with clean water, with a smaller investment in sanitation infrastructure. The *Iimp* has to Caxias do Sul one exactly equal to the conventional practice while Cuenca is very close to best practice, it being understood that the increase in density brings the effect of increasing soil sealing considering how best to practice a higher percentage than the conventional practice, due probably to possess Cuenca impermeable spaces than necessary, since the majority of other indicators have shown that the values for Cuenca are far from the best practices that Caxias do Sul.

It is noticed that the shape of the abacuses of Caxias do Sul and Cuenca is very similar, but Cuenca generally showed worse results than the first. Both cities need to review their sanitation facilities, as well as on issues of density and distribution homes in the territory.

4. CONCLUSIONS

Indicators of "Hidricidade - Urban Efficiency" are practical and relatively simple tools that allow for balanced growth analysis of cities. The diagnostic evaluation of Urban Efficiency through "Hidricidade" indicators in the Caxias do Sul city compared to Cuenca, allowed to establish some existing weaknesses with regard to the management of urban sprawl and water management. Sought are two similar cities to make the comparison, however further analysis is needed to draw conclusions about the two cities and it is up to the application of other indicators proposed in the larger study. It is also suggested to propose new indicators, focused on the specific problems of each place, in this case requiring new benchmarks. The results suggest the need to increase the density and occupy more territory already urbanized. It is noticed that there is still room for growing population, so the urban sprawl should be avoided.

5. REFERENCES

Andrade, L. M. S. 2014. *Conexões dos Padrões Espaciais dos Ecossistemas Urbanos: procedimentos metodológicos com enfoque transdisciplinar para o processo de desenho urbano sensível à água englobando o subsistema da comunidade e o suprassistema da paisagem*. Thesis PhD in Architecture and Urbanism. Faculdade de Arquitetura e Urbanismo, Universidade de Brasília, Brasilia - DF.

Berardi, U. 2013. Clarifying the new interpretations of the concept of sustainable building, *Sustainable Cities and Society* 8: 72-78.

Brandon, P. S. & Lombardi, P. 2011. Evaluating sustainable development in the built environment, *Wiley-Blackwell, Oxford*: 73-87.

CIMES (Org.). Ciudades Intermedias y Urbanización Mundial. Ajuntament de Lleida, UNESCO, UIA, Ministerio de Asuntos Exteriores. Lleida, Spain. 1999.

French, S. P. 2014. Designing more sustainable cities by integrating infrastructure systems. WIT *Transactions on Ecology and the Environment*, V 191. In <www.witpress.com>. Access in: March 2013.

ISBN: 978-85-92631-00-0

Gallopin, G. C. 2012. *Five Stylized Scenarios*. Global Water Futures 2050. UNESCO United Nation World water assessment Program, WWDR4.

Godoy, J. D. 2016. *Harversting rainwater households a strategy in short term to improve the current water metabolism in Cuenca, Equador*. Resurbe II - International Conference on Urban and Regional Resilience – Empowering Local Communities for Local Action. Cuenca, Ecuador.

Hill, K. 2009. Urban Design and Urban Water ecosystems. *The Water Environment of Cities*. Springer. 141-170.

Instituto Brasileiro de Geografia e Estatística. 2010. Aglomerados subnormais. Censo Demográfico. Rio de Janeiro - RJ. In <http://www.ibge.gov.br/home/estatistica/populacao/censo2010/aglomerados_subnormais/>.

Access in: March 2013.

Odum, E. P. & Barret, G. W. 2007. *Fundamentos de Ecologia*. Translation of the 5th American edition. Cengage Learning. São Paulo – SP.

Sistema Nacional de Informações sobre Saneamento. In <http://www.snis.gov.br/>. Access in: March 2013.

Spirn, A. 2011. *Ecological urbanism: A framework for the design of resilient cities*. Massachusetts, United States.

Tanguay, G.A. et al. 2010. Measuring the sustainability of cities: An analysis of the use of local indicators. *Journal Ecological Indicators* 10: 407–418.

Ulian, G. 2015. *Avaliação Diagnóstica para a Gestão Urbana através de indicadores de "Hidricidade"*. Thesis PhD in Architecture and Urbanism. Facultad de Arquitectura, Construcción y Diseño, Universidad del Bío-Bío. Concepción, Chile.

Ulian, G. et al. 2015. *Indicadores de "Hidricidade" como ferramenta de avaliação da eficiência urbana*. In: EuroElecs. 2015 Latin American and European conference on sustainable buildings and communities, 2015, Guimarães. Connecting People and Ideas – Proceedings of EURO ELECS 2015. (2):1181- 1190.

WWI. Worldwacth Institute. 2013. *O Estado do Mundo 2013. A sustentabilidade ainda é possível?* Organização: Erik Assadourian e Tom Prugh. Editora UMA – Universidade Livre da Mata Atlântica - Salvador, BA.