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Comparison of soil use in the infiltration of rainwater: pasture and forest

Comparación del uso del suelo en la infiltración del agua de lluvia: pastos y bosque

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Edson Lopes[1]*, Rosemeri Carvalho Marenzi[1] and Tito César Marques de Almeida[1]

ABSTRACT

Keywords:
Forest fragmentation
Flooding
Climate change

The lowlands of the forests of Itajaí/SC, Brazil were extensively and predominantly fragmented into urban settlements, port facilities, and rice plantations. In addition to climate change events and existing environmental conditions, the region is susceptible to flooding. Consequently, this study aims to analyse the hydrologic functioning of the lowland forests in the infiltration of rainwater in Itajaí. A map of land use and occupation was created using the Geographic Information System – GIS, and crossed with the soil maps of the city. Two areas with the same soil classifications were selected; a pasture area and a forest area. In August and October, these areas were sampled and classified according to the following criteria: grain size, moisture, permeability, and organic matter content of the soils. The infiltration rate of the soils in the sample units was tested using the double ring infiltrometer. Analysis of variance (ANOVA) was used to verify the correlation between the obtained values. The average values for the samples obtained in areas without vegetation were 3.45 cm h^{-1} and 3.60 cm h^{-1} in August and October, respectively. In the area with forest vegetation, the average values were 19.05 cm h^{-1} and 8.70 cm h^{-1} for the samples obtained in August and October, respectively. Although the soil conditions were the same, this study found significant differences in the water infiltration rates in the soil surface between the forest areas and the areas without vegetation. The forest vegetation denotes its potential role in the infiltration of rainwater in the floodplain of area.

RESUMEN

Palabras clave:
Fragmentación del bosque
Inundaciones
Cambio climático

Los bosques de Itajaí/SC, Brazil han sido intensamente fragmentados en la llanura, reflejando en el predominio de asentamientos urbanos, estructuras portuarias y cultivos de arroz. Al sumarse los eventos provenientes del cambio climático a las condiciones ambientales existentes, la región se torna susceptible a las inundaciones. De esta forma, este trabajo tiene como objetivo analizar la función hídrica de los bosques de llanura en la infiltración del agua de las lluvias en Itajaí. Se utilizó el Sistema de Información Geográfica para la elaboración de un mapa de uso y ocupación del suelo y se comparó con el mapa de suelos del municipio. De estos análisis fueron seleccionadas dos áreas en la llanura en la misma clase de suelos, una con pastoreo y una cubierta por bosque. En los meses de agosto y octubre, estas áreas se muestrearon y clasificaron acorde a los siguientes criterios: granulometría, humedad, conductividad hidráulica y contenido de materia orgánica de los suelos. También en estas unidades de muestra se realizó el ensayo de velocidad de infiltración básica (VIB) mediante el método de anillos concéntricos. Se utilizó el análisis de varianza (ANOVA) para verificar el efecto entre las variables obtenidas. Los valores medios obtenidos de VIB para área de pastoreo fueron 3,45 cm h^{-1} y 3,60 cm h^{-1} para los meses de agosto y octubre, respectivamente. En el área con vegetación se obtuvieron valores medios de 19,05 cm h^{-1} y 8,70 cm h^{-1} para los meses de agosto y octubre, respectivamente. En este trabajo fue posible verificar que hay diferencias significativas en la infiltración de agua, en la parte superficial del suelo, entre las coberturas con bosque y con pastoreo, donde las condiciones edáficas son iguales. La vegetación forestal denota su papel potencial en la infiltración de agua de lluvia en la planicie de inundación del área.

[1] Universidade do Vale do Itajaí. Rua Uruguai, 458. Brasil
* Corresponding author: <edsonnlopes@gmail.com>

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The consequences of climate change in Latin America and the Caribbean, according to Herrán (2012), are reduced availability of water, diminished performance of agriculture in low altitude areas, loss of biodiversity, and increase of flooding and droughts.

Between 1992 and 2001, floods were the most frequent natural disaster (43% of 2257 disasters) and affected more than 1.2 billion people all over the world in a decade. These floods are the result of climate change associated with the impact on ecosystems (Millennium Ecosystem Assessment, 2005). In recent years, climate change has been aggravated by natural or anthropogenic causes, or a combination of these (Moraes *et al*., 2015).

According to Frank (1995) the region of Vale do Itajaí, in Santa Catarina, and the municipality of Itajaí in particular, have a history of floods and flooding due to environmental characteristics. The most devastating floods in the region occurred in 1983, 1984, 2001, 2008 and 2011 (Santos *et al*., 2012). The last flood in the city occurred in 2015. Combined with the fact that Itajaí is located on a plain that comprises the mouth of river Itajaí and that it receives the energy and matter inputs of the entire river basin, the forest fragmentation and urbanization of this region increases its susceptibility to floods in rainy periods (Marenzi, 2012). According to Tucci (2008), floods occur in two ways: the riverbanks, because of the temporal and spatial variability of rainfall and runoff in the river basin; and due to urbanization, which occur in urban drainage because of the effect of waterproofing the soil or preventing the flow of water.

Itajaí is located in the Atlantic Forest and it is represented by the Montane Atlantic Forest and Lowland Atlantic Forest (Veloso *et al*., 1991). The lowland coastal forest was extensively fragmented and mostly occupied by settlements, port structures, and agricultural and pasture systems, especially rice crops in the rural area (Marenzi, 2012).

Several works have been carried out to better understand the impacts of urban planning on the hydrological cycle (Barron *et al*., 2013; Braud *et al*., 2013; Davies *et al*., 2008; Miller *et al*., 2014; Randhir and Raposa, 2014; Rougé and Cai, 2014; Sillanpää and Koivusalo, 2015; Suriya and Mudgal, 2012; Yang *et al*., 2014; Dalagnol *et al.,* 2017; Santos *et al.,* 2017) and the effects of irrigated agriculture (Foster *et al*., 2015; Blainski, *et al.,* 2016). Some works specifically sought to analyse the influence of vegetation on water infiltration (Alves *et al*., 2005; Costa *et al*., 1999; Godim *et al*., 2010; Nunes *et al*., 2012; Sidiras and Roth, 1987; Touma and Albergel, 1992; Zwirtes *et al*., 2011; Rossato *et al.,* 2016). However, no works on the subject in the region of Vale do Itajaí, in Santa Catarina were identified.

Based on the history of physical and material damages caused by flood phenomena in Santa Catarina, specifically in the Itajaí Valley, there is a need for research on measures to minimize this trend (Moraes *et al*., 2015). Therefore, this work sought to verify the influence of vegetation cover on the rate of infiltration and physical characteristics of soil inherent to infiltration. Consequently, the aim of this study is to analyse the physical and hydrological characteristics of soil in pasture and forest areas and understand the functional role of forests to provide information on floods in Itajaí.

MATERIALS AND METHODS

The study area is located in the municipality of Itajaí, in the geographical coordinates 26°54'28''S and 48°39'42''W, at an altitude of 2.0 m. Research was conducted from May 2014 to February 2015.

According to the Köppen classification, the regional climate is humid with a warm summer (Cfa). Annual average rainfall in the region is 1545.3 mm, average temperature is 20.3 °C, and average relative humidity is 83.73%. The heaviest rainfall occurs from January to March and from October to December and the lowest rainfall occurs from April to June and July to September (Araújo *et al*., 2006).

Google Earth images were used to classify soil use and occupation and select the sample areas and ArcMap 10.0 software was used to georeference a scene from the urban part of the municipality, with information from the database of the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI, 2004). For the other scenes, we created a mosaic using Regeemy software 0.2.43 (Fedorov *et al*., 2003). ArcMap 10.0 software was used for supervised classification.

The experimental areas were selected according to similar environmental characteristics, like soil, climate and relief although one area consisted of secundary atlantic forest (21.44 ha) and the other consisted of artificial pastures (15.63 ha) with semi-extensive livestock farming. Both areas are situated along the right bank of river Itajaí - Mirim and are classified as Histosols (PMI, 2006).

Two sampling campaigns were executed, one in August (dry season) and one in October (rainy season) of 2014. Soil was collected from four random sampling points in each area to determine moisture content, organic matter content, and grain size. The basic infiltration rate was determined at the location.

Each sample contained five kilos of soil at a depth of 50 cm. For the hydraulic conductivity analysis, soil was collected at a depth of 50 cm to obtain an undisturbed sample of 15 cm in height and 10 cm in diameter.

The basic infiltration rate test was run according to the methodology double ring, described by Bernardo *et al.* (2013), using I=K*T^A, where K and A are constant and depend of the soil. Moisture content was analysed according to EMBRAPA (1997). This methodology was used for grain size analysis of soils rich in organic matter. Fifty grams of soil were weighed in a beaker and portions of oxygen peroxide (H_2O_2) were successively added to the soil. The samples were heated to accelerate the reaction and stirred using a glass rod to observe the effervescent reaction. The addition of H_2O_2 was suspended and the samples were covered with a clock glass and left to sit overnight. This process was repeated another two times. To remove the excess of H_2O_2, water was added to the beaker instead of washing the sample filter paper, as indicated in the methodology. The samples were left to sit overnight, after which the supernatant was withdrawn and the water was restored. Also, this procedure was repeated two more times. The material was put to dry in an oven at 105 ^{o}C for 24 h. The material was buffered and 20 g were weighed and sieved (#0.063 mm) with the addition of water. The retained material was collected and dried in an oven at 105 ^{o}C for 24 h. The weight difference was used to calculate the percentage of silt/clay and, consequently, of sand. Organic matter content of the soil samples was determined using the methodology described by Wright (2008). Permeability was determined using the variable load methodology described by Das (2006).

For the analysis of variance, the following factors were considered: 1) soil cover (forest and pasture); 2) campaign, both considered orthogonal and fixed. The analysed variables were: basic infiltration rate, hydraulic conductivity, moisture content and organic matter content. Normality was verified using the Kolmogorov-Smirnov test and the homogeneity of variances was verified using the Cochran test; when necessary, transformations to Log10 (X+1) were applied (Underwood, 1997).

RESULTS AND DISCUSSION

The municipality of Itajaí presented fairly fragmented areas, mainly by agricultural activities and urban pressure (Figure 1). We defined the following six classes of soil use and occupation: culture, urban patch, reforestation, exposed soil, forest, and water. Once the study area was selected, the following classes were specifically verified: cultivation, exposed soil and vegetation, with a predominance of the former, mainly consisting of pasture for cattle farming. However, this type of farming is not prevalent in the municipality; irrigated agriculture represents most of the cultures in the municipality, occupying 9283 ha, with a production of 69,000 t of grain (EPAGRI, 2010).

The analysis of soil use and occupation showed that the municipality of Itajaí has small portions of forest in the lowlands. According to Bedin (2013), since the 1970s, the urban fabric of Itajaí has expanded rapidly and lots have replaced cultivated areas. Ribas (2013) stresses that in 1985, the cultivation and reforestation areas occupied most of the municipality. Around 1995, the forest cover increased in sparse fragments, possibly resulting from the abandonment of part of the agricultural areas. The urban area also expanded due to the economic dynamics of the region. This expansion caused the process of forest fragmentation, especially in plains that are most sought after for urban expansion, and intensified the problem of soil sealing and flooded areas in periods of intense rainfall. These facts support the importance of understanding the functional role of forest cover in these flood plains. This considering the natural vulnerability to flooding due Itajai location at the mouth of a large river basin (Santos *et al*., 2012; Moraes *et al*., 2015). Natural vulnerability intensifies with the urbanization process (Tucci, 2008). It is also important to consider that climate change intensifies vulnerability, because in many parts of the world there is a significant increase in temperature, resulting in

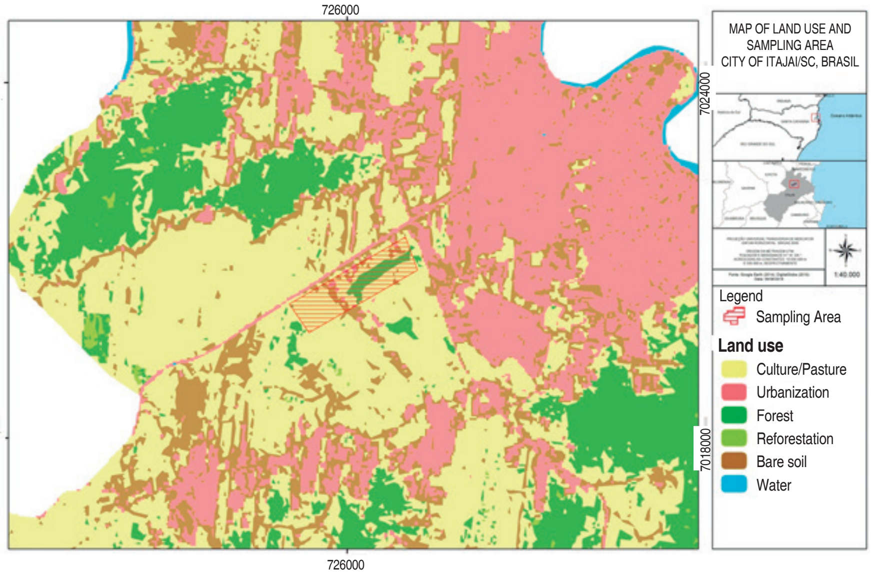

Figure 1. Use and occupation of the municipality of Itajaí (SC), detail of the study area.

extreme events. (Righi and Robaina, 2010; IPCC, 2014), such as floods. The scientific community has reinforced the conviction that climate variability has intensified in recent decades as a result of human activities (Moraes *et al*., 2015). All the analysed samples contained more than 99% of clay. Organic matter content ranged from 13.4 to 51.7%, moisture content ranged from 59.8% and 84.5%, the basic infiltration rate ranged from 0.6 and 39 mm h^{-1}, and conductivity ranged from 0.05 and 1.13 cm h^{-1} (Table 1).

Table 1. Observed values for the variables hydraulic conductivity, moisture content, organic matter content, basic infiltration rate and grain size for two soil covers in Itajaí (SC).

		Hydraulic conductivity (mm h^{-1})		Moisture content (%)		Organic matter content (%)		Basic infiltration rate (mm h^{-1})		Grain Sixe (%)	
		Campaign									
	Sample No.	1	2	1	2	1	2	1	2	1	
		(cm h^{-1})		(%)				(cm h^{-1})		% Clay	% Sand
Cover – Pasture	1	0.21	0.77	80.0	64.8	38.5	46.4	1.2	3.6	99.9	0.1
	2	0.85	0.02	76.0	64.0	37.4	40.1	7.2	3.6	99.8	0.2
	3	0.28	0.32	77.2	59.8	25.9	38.6	4.8	4.8	99.3	0.7
	4	0.59	0.66	84.5	66.9	49.3	31.7	0.6	2.4	99.7	0.3
	Average	0.48	0.44	79.4	63.9	37.8	39.2	3.4	3.6	99.7	0.3
	Min.	0.21	0.02	75.9	59.8	25.9	31.7	0.6	2.4	99.3	0.1
	Max.	0.85	0.77	84.5	66.9	49.3	46.4	7.2	4.8	99.9	0.7
Cover – Forest	5	0.18	0.75	68.6	68.4	37.5	34.3	18.0	3.6	99.8	0.2
	6	0.05	1.13	82.6	59.9	27.0	46.0	39.0	24.0	99.8	0.2
	7	0.13	0.19	81.3	61.9	13.4	46.6	4.8	1.2	99.9	0.1
	8	0.30	0.17	79.3	62.9	34.1	51.7	14.4	6.0	99.8	0.2
	Average	0.16	0.56	77.9	63.3	28.0	44.6	19.0	8.7	99.8	0.2
	Min.	0.05	0.17	68.6	59.9	13.4	34.3	4.8	1.2	99.8	0.1
	Max.	0.30	1.13	82.6	68.3	37.5	51.7	39.0	24.0	99.9	0.2

The differences found for the factor soil cover with the variable basic infiltration rate corroborate the findings of Alves *et al.* (2005) and Zwirtes *et al.* (2011), considering the most of basic infiltration rate in the soils of the forest. However, the values found in the forest area by these authors are significantly higher (116.5 cm h^{-1} and 122.48 cm h^{-1}, respectively). This difference can be associated with the type of studied soil. Histosol or organic soil have hydromorphic organic horizons and these horizons remain saturated with water during a period of the year (Zanella *et al.*, 2018). Therefore, with lower infiltration rate if compared another soils. The moisture content of the soil in the two areas was slightly different, with smaller amounts in the forest area. This can be explained by the fact that larger vegetation areas require more water (Raven, 2007).

The analysis of variance indicated significant differences in relation to cover for the infiltration rate (Table 2). The significantly higher values were in forest areas regardless of the time of the year (Figure 2). The significantly higher moisture content was in campaign 1 for both types of cover (Figure 3).

Table 2. Significance value and F value of the variables: hydraulic conductivity, moisture content, organic matter content and basic infiltration rate obtained in the August and October campaigns of 2014 for different soil covers (forest and pasture), in the city of Itajaí (SC).

	Basic infiltration rate		Moisture content		Organic matter		Hydraulic conductivity	
	P	F	P	F	P	F	P	F
Campaign	0.281	1.2748	<0.0001	47.458	0.057	4.418	0.305	1.145
Cover	0.041	5.250	0.641	0.229	0.625	0.251	0.553	0.372
Campaign Coverage*	0.268	1.351	0.848	0.038	0.102	3.132	0.204	1.807

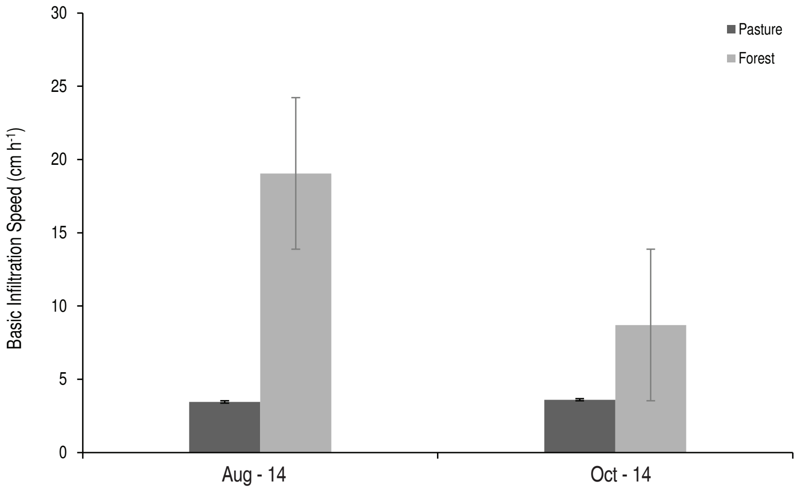

Figure 2. Basic infiltration rate, average and respective standard error, obtained in the August and October campaigns of 2014 for different soil covers (forest and pasture), in the city of Itajaí (SC).

The analysis of variance proved to be significant for the factor campaign and can be explained by the occurrence of increased rainfall in the period. However, there were no significant differences between the soil covers, which suggests the same moisture condition of the analysed soil samples. According to Araújo and Reis (2014), the accumulated volume in August (118 mm) was higher than the accumulated volume of October (63 mm). Therefore, the result of greater moisture in the first campaign is expected.

The high values of clay in all the analysed samples suggest that any difference between the studied areas can be the result of the forest function on the soil, especially in terms of aeration due to the root system (Gliessman, 2000).

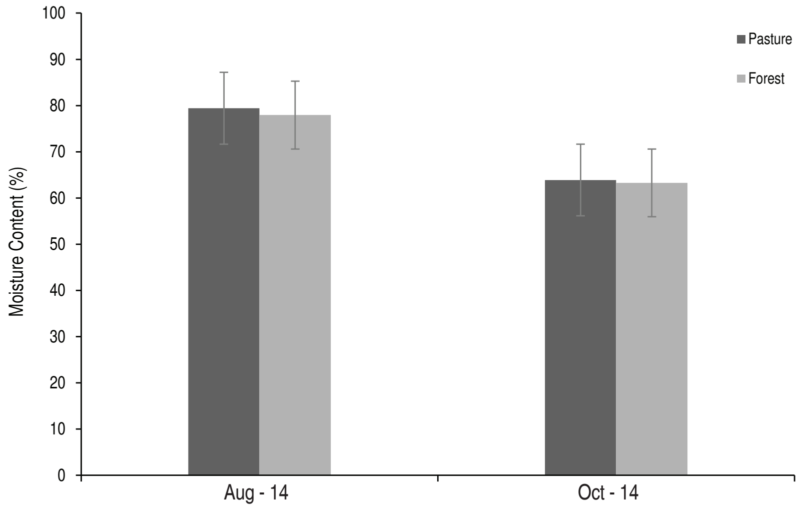

Figure 3. Moisture Content, average and respective standard error, obtained in the August and October campaigns of 2014 for different soil covers (forest and pasture), in the city of Itajaí (SC).

The content of organic matter was numerically smaller in the forest area of the first campaign. This fact cannot be explained since the forest generates the most amount of organic matter, as verified by Cerri *et al.* (1991) and Leite *et al.* (2003), even considering recycling. However, the increase in organic matter content may derive from the semi-extensive livestock farming in the area and the faeces residue. In the October campaign, the organic matter content was numerically greater in the forest area, which is closer to the expected result.

The hydraulic conductivity results followed the same trend of the organic matter content, according to which the presence of cattle could have been more frequent in August (first campaign) since the semi-extensive system generates organic waste that may have contributed to the hydraulic conductivity. In the October campaign, the forest cover was compensated in organic matter and therefore provided greater hydraulic conductivity. Significant correlations were observed between the organic matter and the physical attributes of the soil (Beutler *et al.*, 2001) since organic matter contributes to the increase in the porosity of soil (Khaleel *et al.*, 1981; Logan and Harrison, 1995), and therefore facilitates permeability.

These results indicate the possibility of greater contribution of forest compared to pasture to minimize flooding in Itajaí. Thus, conservation actions and educational programs or actions are extremely important, because they can minimize environmental problems, especially those associated with the silting of the river and soil sealing (Moraes *et al*., 2015).

CONCLUSIONS

The water infiltration was significantly higher in the presence of forest vegetation (*P*=0.041) indicating its potential role in the infiltration by rainwater absorption in the floodplain of Itajaí/SC, Brazil. In this way, the pressure for occupation urban and agriculture stresses the importance of protecting the last forest remnants.

It is important to consider that sampling in one area limited the study, since other samples could confirm the value of the forest in the infiltration of the water in the soil, minimizing the problems of floods, common in the region and intensified by events due to climate change. In any case, the result of this study indicates the importance of transforming the last forest remnants into Protected Areas.

REFERENCES

Alves MC, Suzuki L, Hipólito JL and Castilho SR. 2005. Propriedades físicas e infiltração de água de um Latossolo Vermelho Amarelo (Oxisol) do noroeste do estado de São Paulo, Brasil, sob três condições de uso e manejo. Cadernos do Laboratório Xeolóxico de Laxe, 30: 167-180.

Araújo SA, Haymussi H, Reis FH and Silva FE. 2006. Caracterização climatológica do município de Penha, SC. In: Bases Ecológicas para um desenvolvimento sustentável: estudos de caso em Penha, SC. Universidade do vale do Itajaí, Itajaí: 11-28.

Araújo AS and Reis FH. 2014. Relatório Climatológico. Sintético mensal. Janeiro a Dezembro. Estação meteorológica automática. Itajaí-SC. Universidade do Vale do Itajaí. Centro de Ciências Tecnológicas da Terra e do Mar. Laboratório de Climatologia. (Relatório de pesquisa).

Blainski E, Porras EAA, Garbossa LHP, Pinheiro A. 2017. Simulation of land use scenarios in the Camboriú River Basin using the SWAT model. Revista Brasileira de Recursos Hídricos RBRH, 22(33). doi: 10.1590/2318-0331.011716110

Barron OV, Barr AD and Donn MJ. 2013. Effect of urbanisation on the water balance of a catchment with shallow groundwater. Journal of Hydrology 485: 162-176. doi: 10.1016/j.jhydrol.2012.04.027

Bedin FA. 2013. Ecologia da paisagem como subsídio para a implantação do Parque Municipal da Ressacada – Itajaí, SC. Pós-graduação em Ciência e Tecnologia Ambiental. UNIVALI, Itajai, Brasil. 140 p.

Bernardo S, Soares AA and Mantovani EC. 2013. Manual de irrigação. Eighth edition. Viçosa: 5ª reimpressão.Editora UFV, Viçosa. 625 p.

Braud I, Breil P, Thollet F, Lagouy M, Branger F, Jacqueminet C, Kermadi S and Michel K. 2013. Evidence of the impact of urbanization on the hydrological regime of a medium-sized periurban catchment in France. Journal of Hydrology 485: 5-23. doi: 10.1016/j.jhydrol.2012.04.049

Cerri CC, Volkoff B and Andreaux F. 1991. Nature and behaviour of organic matter in soils under natural forest, and after deforestation, burning and cultivation, near Manaus. Forest Ecology and Management 38: 247-257. doi: 10.1016/0378-1127(91)90146-M

Costa ÉL, Silva AM, Colombo A and Abreu AR. 1999. Infiltração de água em solo, determinada por simulador de chuvas e pelo método dos anéis. Revista Brasileira de Engenharia Agrícola e Ambiental 3:131-134.

Dalagnol R, Borma LS, Mateus P, Rodriguez DA. 2017. Assessment of climate change impacts on water resources of the Purus Basin in the southwestern Amazon. Acta Amazonica [online]. 47(3). doi: 10.1590/1809-4392201601993

Das BM. 2006. Fundamentos de Engenharia Geotécnica. Sixth edition. Thomson Learning, São Paulo. 577 p.

Davies AS, Hernebring C, Svensson G and Gustafsson LG. 2008. The impacts of climate change and urbanisation on drainage in Helsingborg, Sweden: Suburban stormwater. Journal of Hydrology 350: 114-125. doi: 10.1016/j.jhydrol.2007.11.006

EMBRAPA. 1997. Manual de Métodos de Análise de Solo. Centro Nacional de Pesquisa de Solos, Rio de Janeiro. 212 p.

EPAGRI. 2010. Manual Operativo: Competitividade da agricultura familiar de Santa Catarina, Florianópolis. (2) 218 p.

Fedorov D, Fonseca LMG, Kenney C and Manjunath BS. 2003. Automatic registration and mosaicking system for remotely sensed imagery. Anais XI SBSR, Belo Horizonte, Brasil, 05-10 abril 2003, INPE, 317-324.

Foster T, Brozovíc N and Butler AP. 2015. Analysis of the impacts of well yield and groundwater depth on irrigated Agriculture. Journal of Hydrology 523: 86-96. doi: 10.1016/j.jhydrol.2015.01.032

Frank B. 1995. Uma Abordagem para o Gerenciamento Ambiental da Bacia Hidrográfica do rio Itajaí, com ênfase no problema das enchentes. Tese (Doutorado), Programa de Pós-graduação em Engenharia da Produção, Universidade Federal de Santa Catarina, Florianópolis. 345 p.

Gliessman SR. 2000. Agroecologia: Processos Ecológicos em Agricultura Sustentável. Trad. Sob a direção de Maria José Guazzelli. Ed. Universidade/UFRGS, Porto Alegre. 658 p.

Gondim TMS, Wanderley JAC, Souza JM, Feitosa JC and Sousa JS. 2010. Infiltração e velocidade de infiltração de água pelo método do infiltrômetro de anel em solo areno-argiloso. Revista Brasileira de Gestão Ambiental 4(1): 64-73. doi: 10.18378/rbga.v4i1.490

Herrán C. 2012. El cambio climático y sus consecuencias para A.L. Fundación Friedrich Ebert, México. 8 p.

IPCC – Intergovernmental Panel on Climate Change. 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspect. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Khaleel R, Redde KR and Overcash MR. 1981. Changes in soil pshysical properties due to waste applications: a review. Journal of Environmental Quality 10: 133-141. doi: 10.2134/jeq1981.00472425001000020002x

Leite LFC, Mendonça ES, Neves JCL, Machado PLOA and Galvão JCC. 2003. Estoques totais de carbono orgânico e seus compartimentos em argissolo sob floresta e sob milho cultivado com adubação mineral e orgânica. Revista Brasileira de Ciência do Solo 27: 821-832.

Logan TL and Harrison BJ. 1995. Physical characteristics of alkaline stabilized sewage sludge (N-Virosoil) and their effects on soil physical properties. Journal of Environmental Quality, 24: 153-164. doi: 10.2134/jeq1995.00472425002400010022x

Marenzi RC. 2012. Bioma Mata Atlântica. pp 118-123. En: Polette M, Marenzi RC, Santos CF (Org.). Atlas Socioambiental de Itajaí. UNIVALI, Itajaí. 305p.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. 155p.

Miller JD, Kim H, Kjeldsen TR, Packman J, Grebby S and Dearden R. 2014. Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover. Journal of Hydrology 515: 59-70. doi: 10.1016/j.jhydrol.2014.04.011.

Moraes AS, Marenzi RC and Longarete C. 2015. Percepção de atores sociais de Itajaí (SC) a respeito das variações climáticas, com foco nas Inundações. Desenvolvimento e Meio Ambiente 35: 411-428. doi: 10.5380/dma.v35i0.40275.

Nunes JAS, Silveira MHD, Silva TJA, Nunes PCM and Carvalho KS. 2012. Velocidade de infiltração pelo método do infiltrômetro de anéis concêntricos em Latossolo Vermelho de Cerrado. Enciclopédia Biosfera 8: 1685-1692.

PMI. Prefeitura Municipal de Itajaí. 2006. Mapa Pedológico. Itajaí, Plano Diretor de Itajaí. Escala 1:100.000.

Randhir TO and Raposa S. 2014. Urbanization and watershed sustainability: Collaborative simulation modeling of future development states. Journal of Hydrology 519: 1526-1536. doi: 10.1016/j.jhydrol.2014.08.051.

Raven PH. 2007. Biologia Vegetal. Seventh edition. Editora Guanabara Koagan SA, Rio de Janeiro. 850 p.

Ribas GS. 2013. Análise espacial e temporal da dinâmica de alteração da cobertura florestal de Itajaí, SC, entre os anos de 1985 e 2013. Trabalho de Conclusão de Curso. UNIVALI, Itajaí.

Righi E and Robaina SEL. 2010. Enchentes do Rio Uruguai no Rio Grande do Sul entre 1980 e 2005: uma análise geográfica. Sociedade & Natureza 22(1): 35-54.

Rougé C and CAI X. 2014. Crossing-scale hydrological impacts of urbanization and climate variability in the Greater Chicago Area. Journal of Hydrology 517: 13-27. doi: 10.1016/j.jhydrol.2014.05.005.

Rossato H, Botta Gf, Becerra AT, Tardito H, Leveratto M. 2016. Problemáticas del cambio climático en la Ciudad Autónoma de Buenos Aires - aportes de las cubiertas vegetadas en la regulación térmica. Revista de la Facultad de Ciencias Agrarias Universidad Nacional de Cuyo [online]. 48(1).

Santos CF, Tornsquit CS, Marimon MPC and Brassanini T. 2012. Enchentes e inundações. 241-245. En: Polette M, Marenzi RC, Santos CF (Org.). Atlas Socioambiental de Itajaí. UNIVALI, Itajaí. 305p.

Santos KA, Rufino IAA, Barros-Filho MNM. 2017. Impactos da ocupação urbana na permeabilidade do solo: o caso de uma área de urbanização consolidade em Campina Grande – PB. Engenharia Sanitaria e Ambiental 22(5): 943-952. doi: 10.1590/S1413-41522016146661

Sidiras N and Roth CH. 1987. Infiltration measurements with double-ring infiltrometers and a rainfall simulator under different surface conditions on an Oxisol. Soil and Tillage Research 9(2): 161-168. doi: 10.1016/0167-1987(87)90082-1

Sillanpää N and Koivusalo H. 2015. Impacts of urban development on runoff event characteristics and unit hydrographs across warm and cold seasons in high latitudes. Journal of Hydrology 521: 328-340. doi: 10.1016/j.jhydrol.2014.12.008

Suriya S and Mudgal BV. 2012. Impact of urbanization on flooding: The Thirusoolam sub watershed – A case study. Journal of Hydrology 412: 210-219. doi: 10.1016/j.jhydrol.2011.05.008

Touma J and Albergel J. 1992. Determining soil hydrologic properties from rain simulator or double ring infiltrometer experiments:a comparison. Journal of Hydrology 135: 73-86.

Tucci CEM. 2008. Águas urbanas. Estudos Avançados 22(63): 97-112:0103- 4014. doi: 10.1590/S0103-40142008000200007.

Underwood AJ. 1997. Experiments in ecology: Their logical design and interpretation using analysis of variance. Cambridge University Press, New York, NY. 504 p.

Veloso HP, Rangel-Filho ALR and Lima AJC. 1991. Classificação da vegetação brasileira, adaptada a um sistema universal. Rio de Janeiro: IBGE – Instituto Brasileiro de Geografia e Estatística. Departamento de Recursos Naturais e Estudos Ambientais. Rio de Janeiro. 124p.

Wright AL, Wang Y and Reddy KR. 2008. Loss-on-Ignition method to assess soil organic carbon in calcareous everglades wetlands. Communications in Soil Science and Plant Analysis 39(19-20): 3074-3083. doi: 10.1080/00103620802432931.

Yang J, Entekhabi D, Castelli F and Chua L. 2014. Hydrologic response of a tropical watershed to urbanization. Journal of Hydrology 517: 538-546. doi: 10.1016/j.jhydrol.2014.05.053.

Zanella A, Ponge JF, Juilleret J, Waal R, Bayon R-C, Vacca A and Andreetta. A. 2018. Terrestrial humus systems and forms – Hydro intergrades. Applied Soil Ecology 122: 87–91.

Zwirtes AL, Spohr RB, Baronio CA, Rohr MR and Menegol DR. 2011. Caracterização físico-hídrica de solos submetidos a diferentes manejos. Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias 4: 51-66.