ANALYSIS OF BEST MANAGEMENT PRACTICES PERFORMANCE'S FOR THE CONSTITUTION OF GREENWAYS IN FORTALEZA-CE.

ANÁLISE DO DESEMPENHO DAS MELHORES PRÁTICAS DE MANEJO PARA CONSTITUIÇÃO DE CORREDORES VERDES EM FORTALEZA-CE.

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Abstract

Aguanambi Avenue is in the city of Fortaleza – CE, and it is susceptible to flooding on rainy season. Green infrastructure is an important alternative to complement conventional infrastructure and consolidate urban resilience. With the main goal to propose the greenway's implementation in Fortaleza's road system, this research has developed a method to analyze the performance of Best Management Practices in mobility corridors. The proposal has distributed management techniques according to the road hierarchy established by the Land Use and Occupancy Law. The precipitation volume admitted is 65.2mm / h, with 10-year return time. The bioswales had better performance in express and arterial streets, with greater size; the rain gardens and flowerbeds responded better in collector and local roads, considered of smaller size.

Keywords: Green infrastructure. Urban Resilience. Best Management Practices. Greenways.

Resumo

A Avenida Aguanambi, situada na cidade de Fortaleza, CE, é conhecida pela suscetibilidade a alagamentos em períodos chuvosos. A infraestrutura verde é uma importante alternativa para complementar a convencional e consolidar a resiliência urbana nas vias. Com o objetivo principal de propor a implantação de corredores verdes no sistema viário de Fortaleza, CE, foi desenvolvido um método de análise do desempenho das melhores práticas de manejo em corredores de mobilidade. As técnicas de manejo foram distribuídas com base na hierarquia viária estabelecida pela Lei de Parcelamento, Uso e Ocupação do Solo. A precipitação admitida para a cidade foi de 65,2mm/h com tempo de retorno de dez anos. As biovaletas apresentaram melhor desempenho em vias expressas e arteriais, de maior porte; os jardins de chuva e canteiros pluviais responderam melhor em vias coletoras e locais, consideradas de menor porte.

Palavras-chave: Infraestrutura Verde. Resiliência Urbana. Melhores Práticas de Manejo. Corredores Verdes.

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1. Introduction

Cities grew over a natural landscape. Fortaleza, like many Brazilian metropolis, had its urban expansion at the expense of the degradation of several natural resources, such as rivers, lagoons, dunes and mangroves (NETO; ALBUQUERQUE, 2014).

The gray infrastructure, defined as built systems in the cities to enable water and energy supply, rainwater catchment, sanitation, the road system and everything that supports human settlements (BONZI, 2017), has led to segregation of natural areas and has caused several environmental problems for cities, such as pollution of water resources, landslides, floods and generation of heat islands. Thus, it is clear that the public policies in Fortaleza adopted urban interventions based on solutions from the last century, according to Bonzi (2017):

> "Under the pretext of hygiene and capitulated by civil engineering, urban planning of the twentieth century imagined it possible to do without plant cover and natural resources as technical solutions dribbled the hydrological cycle. Soils have been waterproofed by increasing rainwater runoff, and natural drainage lines have beenreplacedbyrainguttersdesigned to lead the water quickly and invisibly, a sinister expedient that transfers the unwanted volume of water to a downstream community." (BONZI, 2017 p. 2)

Thew hich confirms that this type of solution is adopted a priori, Municipality of Fortaleza is constructing stations above the Água Nambi creek to house the BRT (Bus Rapid Transit) transport system. In this way, another water resource of the city will be buried. The budget estimated at 95 million reais (PREFEITURA DE FORTALEZA, 2017), is promoting the blocking of 36% of the channel surface and the construction of an auxiliary gallery for rainwater harvesting. According to the City Hall of Fortaleza (2017):

"Budgeted at R$ 95 million, with the viaduct and footbridge released in March of this year, the works started in February 2016 and are part of the Messejana / Centro Express corridor, which provides for various interventions in the region, such as the road rehabilitation of Aguanambi Avenue, with the implementation of a new drainage system, sidewalks, four kilometers of bike path, installation of eight bus stations near the central site,besides the urbanization and renovation of two squares and the roundabout existing under the new viaduct. The second stage of the project, which provides for the expansion of urbanization of Av. Aguanambi, is scheduled to be completed by January 2018." (FORTALEZA PREFECTURE, 2017, web).

Given this fact, the intervention at Aguanambi Avenue shows that the application of the gray infrastructure was the main solution of the project admitted to enable the implementation of the BRT corridor.

Waterlogging reports on the avenue cited prove the impact of the poorly planned interventions of the last decades that did not consider the natural characteristics of the site such as topography, water resources and floodplains. On January 8, 2017, a 55.6mm precipitation occurred in the morning that caused the Aguanambi channel to overflow (G1 CE, 2017) (Figure 1). Technically, this means that in the area of 1,00m^2 a blade of 55.6mm or 5.5cm in height formed on the ground. It may not seem like much, but in vulnerable regions such as Aguanambi, the consequences of this type of climate event are disastrous.

Therefore, given this information, the problem identified is the vulnerability of Fortaleza's road system to natural events, such as intense precipitation, urban sprawl (BONZI, 2015) and interventions promoted over the years to improve urban mobility, leading to intense waterproofing of the soil.

Adaptive interventions in cities are essential for urban resilience, but only if applied through systems based on ecology (CHELLERI et al 2015). Green Infrastructure is defined as a network of interconnected green areas that promotes a range of environmental benefits such as climate regulation and biodiversity preservation (BENNEDICT and MCMAHON, 2006). The LID (Low Impact Development) has developed in the last years as one of the main al-

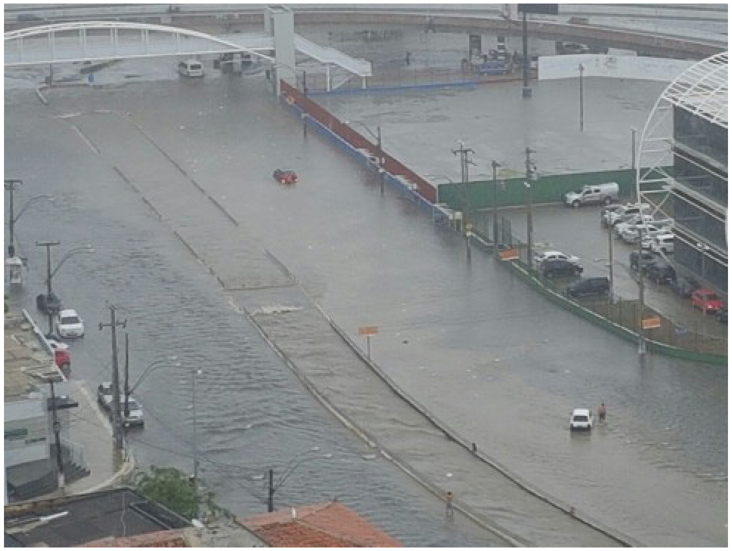


Figure 1 - Channel of Aguanambi overflowed in rainy day. Source: G1 CE (2017)
Available at: <http://g1.globo.com/ceara/noticia/2017/01/com-chuva-carros-boiam-na-avenida-aguanambi-em-fortaleza.html> Acessed on 20 mar. 2017.

Figure 2 - Benefits of implementing Green Infrastructure in the streets Source: Gehrels et al (2016)
Available at: <http://www.adaptivecircularcities.com/wp-content/uploads/2016/07/T02-ACC-WP3-Green -Blue-infrastructure-for-Healthy-Urban-Living-Final-report-160701.pdf > Accessed on 18 Nov. 2017

ternatives for the constitution of a Green Infrastructure in public and private spaces through the application of rainwater management techniques; also known as BMP (Best Management Practices) According to Gehrels et al (2016), the Green Infrastructure applied in streets and avenues through BMP can offer many ecological services that contribute to urban resilience (Figure 2).

The consolidation of Green Corridors in the road system through BMP can promote the connection between the ecological poles by configuring a Green Infrastructure, which plays an important role in the accomplishment of environmental services of provision, support and purification (HUBER et al., 2010).

The objective of this research is to develop guidelines to guide the formation of a network of Greenways through Fortaleza's mobility corridors, with a broader distribution of stormwater management techniques from a local scale to the municipal scale (Figure 3). These guidelines are in line with the parameters established by the new LUOS (Law of Land Parceling, Use and Occupancy of Fortaleza) for the city's road system.

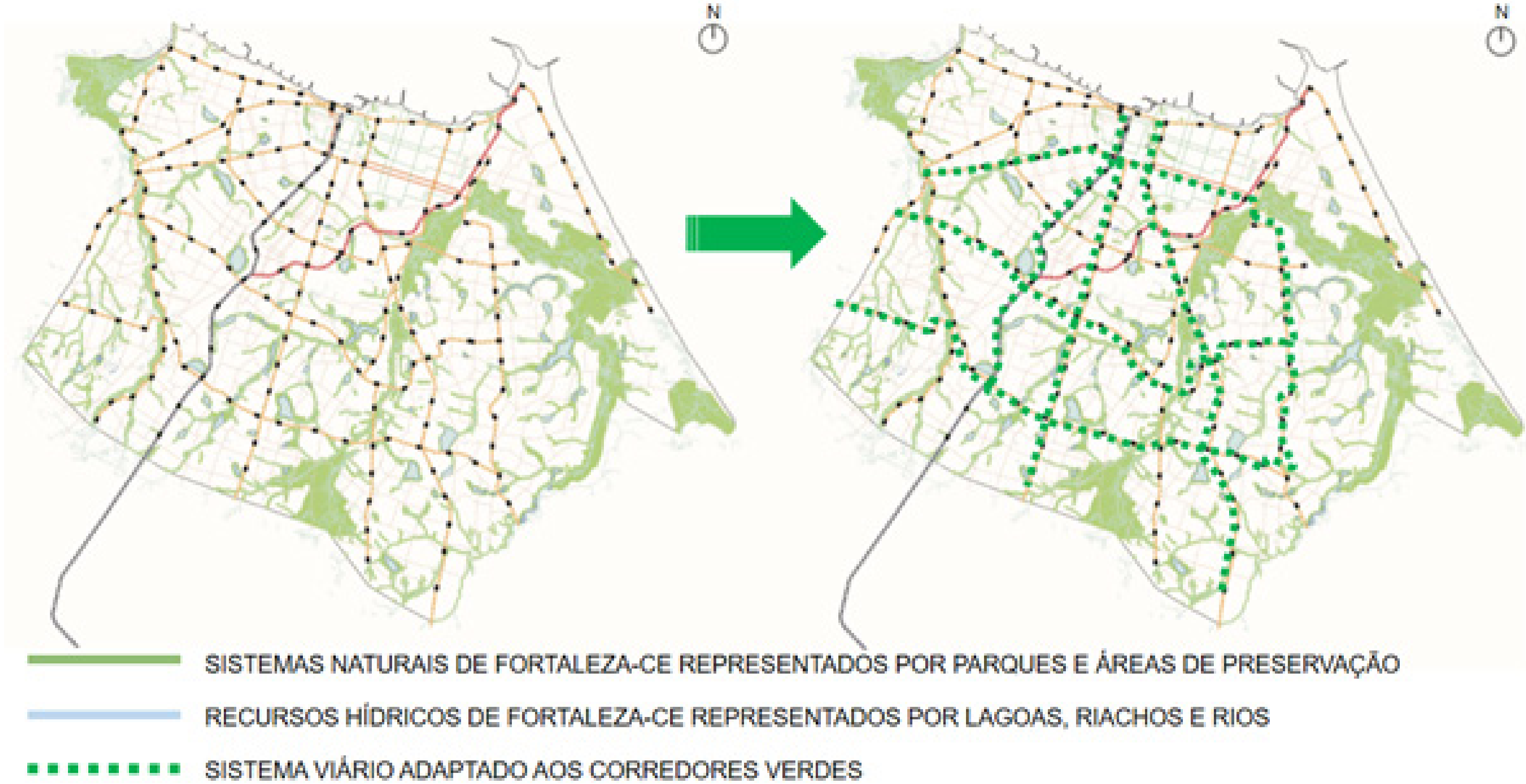


Figure 3- Adaptation of the road system to the Green Corridors
Source: adapted from Fortaleza 2040 (2015)

2. Review of the literature on the relationship between the road system and greenways and the applicability of BMP in mobility corridors

According to Little (1990) and Yu, Li and Li (2006), Green Corridor is a linear free space that is wooded along a natural corridor, that is,along rivers, the coast, a valley or along converted roads or roads in areas for recreation and leisure, such as a landscape or river channel. Little (1990) also defines the concept under analysis as a wooded mobility corridor geared towards the movement of pedestrians and cyclists, acting as a connector between squares, parks, nature reserves, and historical sites.

These green connections are key pieces of urban planning; the dissemination of this solution represents a great potential for the recovery of natural resources in cities, states or countries (FABOS, 1995). These corridors may have different widths and behave like a connected, directional network, such as streets, avenues, or roads. The main difference between natural and artificial green corridors is that in the former nature is the main infrastructure and their network of connections is considered pre-existent (FABOS, 1995).

AccordingtoYu, Li and Li(2006), green corridors along rivers, canals or streams have proven the importance of planting afforestation along the banks of these water resources as an effective way to prevent flooding. The Chinese, as well as other peoples around the world, suffer greatly from the overflow of rivers, so the creation and preservation of green areas on the riverbanks began to improve the drainage system around these places.

In this research was elaborated a survey of the functions attributed to the Green Corridors by the main authors who discussed the theme in the last two decades (Chart 1).

Chart 1 shows that two of the listed authors describe the Greenways as basic elements for the composition of a green infrastructure; and according to Benedict and Mcmahon(2006) the Green Infrastructure is composed of the connection between poles and fragments. Yu, Li and Li (2006) and Little (1990) establish a relationship between the Green Corridors and the axes of transport and mobility, represented by streets, avenues and roads.

The constitution of Green Corridors in the road system is based on the compatibility of some techniques of Best Management Practices with the mobility axes. According to Portland (2016) the following BMP are more appropriate for use in streets, avenues and roads:

- Bioswales
- Rain Gardens
- Rain flowerbeds
- Curb extension
- Tree boxes
- Pervious pavement

The characteristics and specificities of BMP influence the definition of its location on the road system, since each one has minimum dimensions and specific requirements to perform its functions correctly (PGCO, 1999B; HUBER et al., 2010; PORTLAND, 2016). Further investigation presents the attributions of these landscape compositions for the accomplishment of environmental services. It is important to understand the functions relate to infiltration [1], evapotranspiration [2] and phytoremediation [3], three essential attributes in the performance of BMP for the implementation of ecological services.

1. Infiltration is the process of water percolation in the soil and can happen in variable ways, depending on the type of soil. Therefore, water can reach the water table, flow horizontally to a river or irrigate the vegetation (DOD, 2004)

2. Evapotranspiration is the loss of soil's water by evaporation and transpiration. Evaporation is the return of moisture to the atmosphere through vegetation; this moisture is absorbed from the soil by the roots and released through the leaves. The rate of evapotranspiration depends on air, temperature, humidity, wind speed, sunlight intensity, vegetation type and soil conditions (DOD, 2004).

3. Phytoremediation is the name of the technology that uses the natural processes of the plants and their interactions with the microbiota in the environment depollution. It has been referred as the most cost-effective, non-invasive and publicly accepted method for treating contaminated environments (Ruby; Appleton, 2010 apud Pinheiro, 2017).

Chart 1 - Comparison of functions assigned to the greenways

AUTHORS	FUNCTIONS OF THE GREENWAYS
Little (1990)	- Recovery of free spaces with the creation of Green Corridors along neglected water resources like rivers or the maritime fronts. - Recreation through paths and trails along disabled railways or channeled rivers. - Preservation of natural corridors to ensure connectivity between species, maintenance of fauna and flora, development of study and physical activities for population as walks. - Facilitate pedestrian access to historical and cultural routes. - Opportunity to enable the implementation of Green Infrastructure at municipal or regional scale.
FABOS (1995)	- Creation of ecological corridors and systems along rivers and the sea coast, for the preservation of fauna and flora - Establishment of corridors focused on leisure and recreation, through the valorization of the landscape in urban or rural areas and with different scales of application (local, regional, national or international) - Historical and cultural valuation aimed at tourism with the objective of promoting educational, leisure and economic and social development activities.
Yu, Li e Li, (2006)	- Preventing floods to the logo of rivers and canals. - Creation of shaded areas, shelter and improved drainage along streets, roads and highways.
Benedict e Mcmahon (2006)	- Recreation and health for the people. - Enhance historical and cultural value in communities. - It allows the establishment of a Green Infrastructure network through the connection of farms, ranches and forests.

Chart 1 - Comparison of functions assigned to the greenways
Source: prepared by the author

2.1 Characterization of Best Management Practices

After introducing the general attributes of the BMP, it is necessary to present the specificities of biovalettes, rain gardens, rain flowerbeds, curbs extension, tree boxes, and pervious pavement with the intention of elaborating guidelines for their implantation in the road system from Fortaleza.

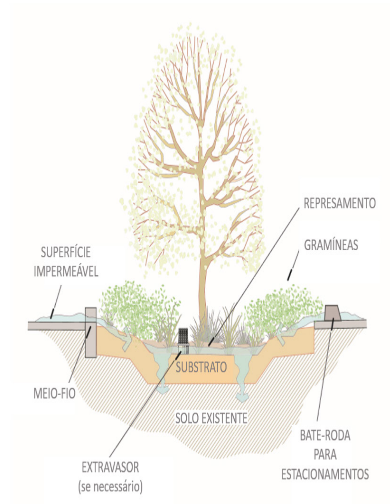
2.1.1 Bioswales

Bioswales are open, smoothly sloping vegetation channels designed to transport rainwater flow, eliminating the need for costly conventional drainage systems. The main function of the bioswale is to treat the flow of rainwater. The treatment occurs through infiltration. Bioswales are usually located along roads, wide streets and parking lots (Figure 4). These require support devices to direct water flow and manage surplus volume (HUBER et al., 2010).

According to Cormier and Pellegrino (. 2008, p 132) "fits to rain gardens make the most of the infiltration of ground work, but bioswales also contributes, filtering the pollutants brought by the runoff along its substrate and the implanted vegetation." Bioswale can be excellent replacements for the conventional drainage system, especially when it becomes obsolete because of increased runoff, often triggered by the intense water proofing of the soil. With these natural ditches fulfilling their role, conventional infrastructure can function as a backup of surplus water during heavy rains (BONZI, 2015).

2.1.2 Rain Gardens

A rain garden is a vegetated depression to infiltrate, but does not retain the runoff, is also known as a biorretention system (Huber et al, 2010). The rain gardens combine layers of organic



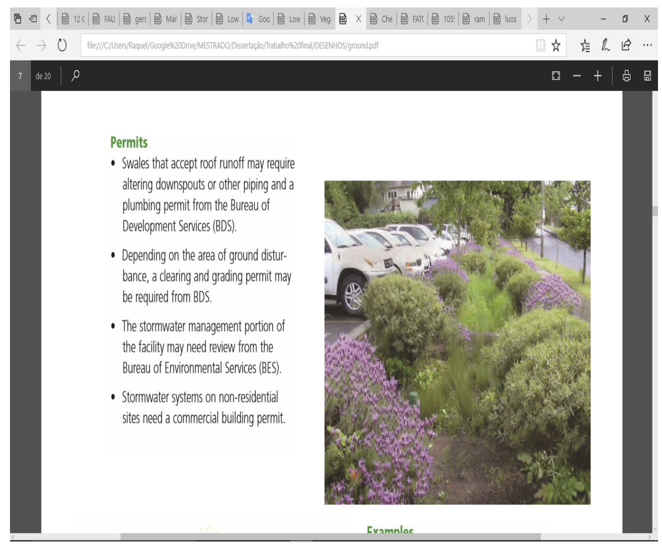


Figure 4 - Bioswales
Source: adapted Handbook (s / d)

sandy soil and substrate to infiltrate and promote microbial activity respectively. Native plants are recommended based on their intrinsic synergies with local climate, soil and moisture conditions without the use of fertilizers and chemicals (op.cit.). According to Bonzi (2015), these vegetation beds can promote the following ecological services:

- Reduction of pollutants transported by rainwater through phytoremediation processes, as the flow passes through the plant community and through the soil;
- Formation of small natural habitats;
- Increased air humidity due to the evapotranspiration process related to plant metabolism.
- Rain gardens are best applied on a relatively small scale and work well along sidewalks and in low areas (Figure 5). Its location should be at least 3 meters away from the buildings to avoid infiltration of water into the foundations or underneath thehouses,causing moisture problems (PGCO, 1999b). Locating them away from large trees allows exposure to sunlight so the gardens can dry in the period between precipitations (Huber et al. 2010).

On the implementation of this management technique, "the correct dimensioning of a rain garden should also pay attention to the fact , a few hours after an event, there should be no standing water on its surface."(CORMIER; PELLEGRINO, 2008 p.129). "Rain gardens must have extravasation mechanisms to withstand more intense rainfall" (BONZI, 2015 p.108).

2.1.3 Rain Flowerbeds

Rain flowerbeds are like compact rain gardens, suitable for reduced urban spaces (Figure 6). This technique do not necessarily have the function of infiltration as the rain gardens, but perform water cleaning through phytoremediation, evapotranspiration

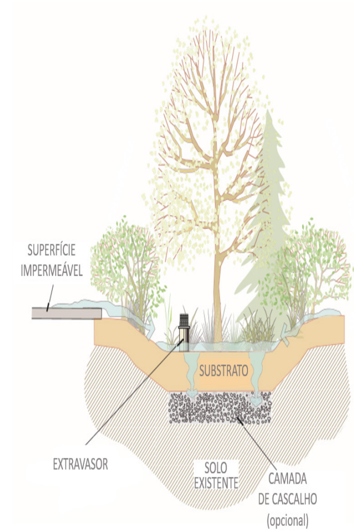


Figure 5 - Rain gardens
Source: Adapted from Handbook (s / d) - left, and personal collection of the author – right

and extravasation can help the beds with infiltration capacity (CORMIER; PELLEGRINO, 2008). The criteria for vegetation definition are the same as those used in rain gardens, and when there is no infiltration, it is interesting to indicate species with high evapotranspiration rates to avoid the accumulation of standing water (PINHEIRO, 2017)

2.1.4 Curbs Extension

Green gutters, also known as curb extension, are typically used in adaptation situations to manage the runoff. They can create places to manage rainwater when existing sidewalk space is constrained or inadequate. Green gutters intercept and send rain water from the street to gently sloping facilities similar to rain gardens. Within the facility, vegetation and control barriers slow the flow, filter, and most often, allow its infiltration into the soil (SEMCOG, 2008).

This BMP typology can be improved through curved design, safety of drivers, pedestrians and cyclists, reducing cross-over distance, and promoting speed reduction in cars (PORTLAND, 2016). According to Bonzi (2015), the sinuosity of the sidewalk extensions interferes positively in the road system, creating the traffic calming and reversing the priority of the vehicles on the pedestrians based on the insecurity (Figure 7) (BONZI, 2015).

2.1.5 Tree Boxes

The tree boxes consist of a small space full of modified soil and planted with a tree. The tree roots treat and absorb the runoff captured from the street to the flowerbed. Resistant shrubs and herbaceous plants tolerant to flooding can also be grown in this space (HUBER et al., 2010). These sites (Figure 8) can be incorporated into urban interventions to promote various environmental benefits (HUBER et al., 2010; PORTLAND, 2016):

- Improving water quality;

Figure 6 – Rain flowerbed
Source: adapted from Handbook (s / d) - left, and author's personal collection – right

- Reduction of heat island effect;
- Decreased absorption of heat from the impermeable floor;
- Reduced heating of rainwater flowing through this surface.

2.1.6 Pervious pavement

The pervious paving system is supported by underground layers of soil, gravel and sand to increase storage and maximize rain infiltration rates. It consists of techniques for impermeable areas reduction and contribute to the reduction of runoff and promote the rainwater absorption (Portland, 2016). This type of pavement reduces and distributes the volume of the flow promoting the removal of pollutants and encouraging the supply of the underground layers (Huber et al, 2010).

According to Portland (2016), permeable asphalt, porous concrete and other permeable coatings can be used in virtually all pedestrian areas, as well as residential sidewalks and parking lots. For streets, the design and type of pavement must be planned and specified by an engineer or architect. The reduction of the heat island effect is possible by using materials with surfaces that do not heat with solar irradiation (HUBER et al, 2010). The permeable floor (Figure 9) is more susceptible to difficulties and failures during construction, so it is important that its application is carried out properly to prevent problems in the future (SEMCOG, 2008). For the effectiveness of this type of material it is important to define its location correctly, because there are types of soil with low absorption capacity. Performing periodic maintenance is critical to its good performance (BONZI, 2015).

Figure 7 – Green gutters are landscape areas on the side of the street that store, filter and infiltrate the runoff of rainwater.
Source: Portland (2016 pp. 2-75, 2-70) Author: Henry Ngan
Available at <https://www.portlandoregon.gov/bes/64040 > Accessed on: 25 Oct. 2017

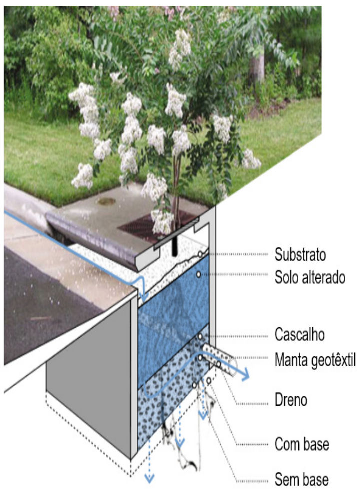


Figure 8 – Tree boxes
Source: adapted Huber et al (. 2010 p 177) - left and Portland (. 2016 p 2-53) –right

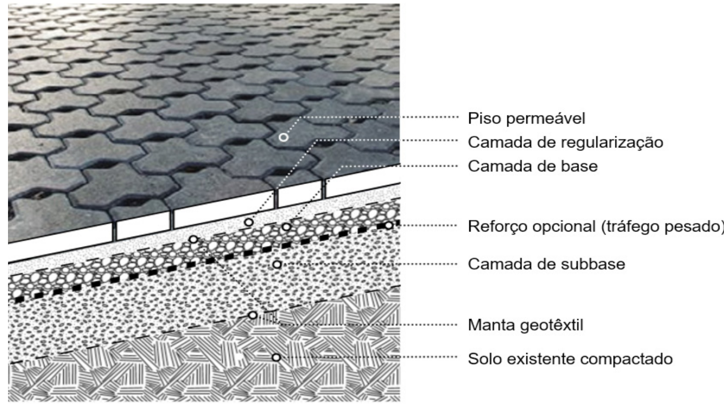


Figure 9 - Permeable pavement
Source: adapted from Huber et al (. 2010 p 173)

3 Methodology

To find the volume of rain, scale and distribute the Best Management Practices in the road system, and set your volume retention, it was necessary collect and indicate some data:

- Return time in years to be applied;
- Intensity of higher precipitation;
- Runoff coefficient - 0,9 (Araújo, 2012);
- BMP dimensions and location;
- Rainwater bioretention volume of BMP

3.1 Definition of the return time and the highest rainfall intensity

The return time is the time space determined for the design of microdrain and macrodrain works (SILVA; PALÁCIO JÚNIOR; CAMPOS, 2013); consists of predicting the greatest rainfall that can occur within a period that generally ranges from 5 to 100 years. To reach the results regarding the BMP efficiency, it was essential to find the precipitated rainfall volume in the study area, this volume depends on the time of return established for projects implementing these management techniques, which according to Portland (2016) is 10 according to categories 1 and 2 described below (Chart 2). This period is indicated to guarantee the efficiency of projects in the short, medium and long term.

Therefore, 10 years will be the indicated value of the return time for the calculation of rainfall intensity. It is worth mentioning that this time and the rainfall index adopted are recommended for urban micro drainage projects in small drainage basins (less than 2.5 km^2) in the city of Fortaleza and its metropolitan region (SILVA, PALÁCIO JÚNIOR; CAMPOS, 2013) . The estimated maximum rainfall intensity (mm / h) for the capital of Ceará for 60 minutes, with a return time of 5 to 100 years (Table 1), is estimated.

The value of 65.2 mm / h is multiplied by the defined area and its runoff with the aim of defining the amount of rain through the rational method V = A x Dp x runoff (LIMA, 2016).

Where:

V is the volume of rain to be found

Δ**p** = rainfall intensity of 65.2 mm / h (SILVA, PALÁCIO JÚNIOR; CAMPOS, 2013).

Runoff is the coefficient of surface runoff that can vary from 0 to 1 (ARAÚJO; ALMEIDA; GUERRA, 2005).

Chart 2 - Indication of the return time to be adopted for the implantation of rain gardens.

REQUIREMENTS FOR WATER MANAGEMENT PLUVIAL	
Types of management techniques of rainwater	Requirement management rainwater based on the return time (RT)
Waterproof area reduction with green roofs, permeable floors and afforestation.	There are no additional requirements for this type of management technique
Category 1: Drainage through rain gardens without extravasation	Precipitation for a return time of 10 years.
Category 2: Drainage through rain gardens or permeable pavement with extravasation and installation for infiltration (underground piping).	Precipitation for a return time of 10 years and meeting the requirements of control of the underground infiltration.
Category 3: Drainage through rain gardens with extravasation to existing drainage network or water resource	Precipitation for a return time which can vary between 2 and 25 years.
Category 4: Drainage through rain gardens with extravasation for combined drainage and drainage system	Precipitation for a return time that can vary between 10 and 25 years.

Source: Portland (2016)

Table 1 – Maximum intensity likely for a storm 60 minutes in Fortaleza and metropolitan area.

MAXIMUM STRENGTH (MM / H)							
Duration (min)	Return Period						
	5 years	10 years	15 years	20 years	25 years	50 years	100 years
60	55,4	65,2	70,6	74,5	77,5	86,6	95,6

Source: Smith, Jr. Palace and Fields (2013)

3.2 Performance of BMP from the standards established in the LUOS

In this section, the performance of the BMP applicable to the mobility corridors was evaluated according to the standards of the circulation routes specified in the Law on Land Parceling, Use and Occupancy (2017) of the city of Fortaleza - CE. In 2017, LUOS was revised and updated to regulate new land use and land use regulations in accordance with the new consolidated scenario in recent years through urban sprawl.

According to the Law, Fortaleza's basic road system consists in two Systems: I - Basic Structural Road System; and II - Basic Complementary Road System (LUOS, 2017). The structural system consists in Express and Arterial I pathways, responsible for the regional and municipal articulation road system. The complementary system consists in Arterial II, Collectors, Local pathways, which collect and distribute car traffic from neighbourhoods to Express and Arterial I pathways (op. cit.) (Chart 3).

Chart 3 – Road System Classification by Land Use and Occupancy Law (2017)

Road System Classification
Expressways
Arterial Pathways I
Arterial Pathways II
Collectors
Landscape Paths
Commercial Routes
Tourist Corridors
Local route

The following standards of routes dimensioned by LUOS (2017) were used to carry out a performance analysis of the Best Management Practices: expressway, arterial route, collector pathway and local route (Table 2).

Table 2 - Dimensions established for the Fortaleza road system

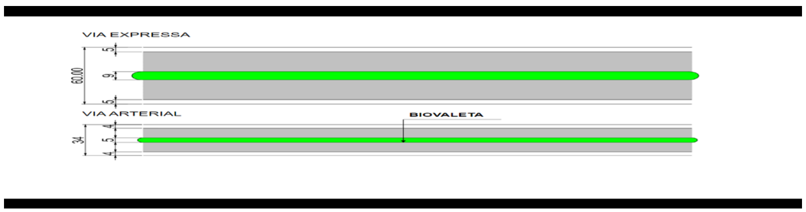
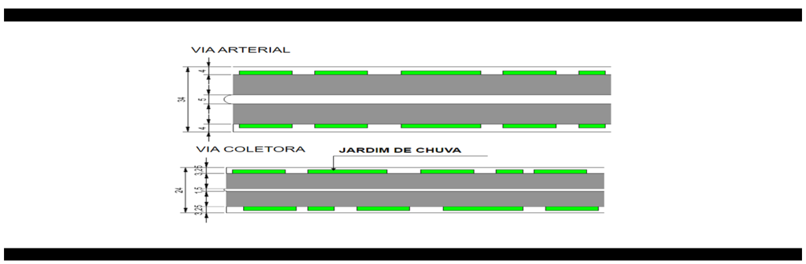
FEATURES	ROAD FOR VEHICLES							
	EXPRESS		ARTERIAL		COLLECTOR		LOCAL	
	Normal Section	Reduced Section	Normal Section	Reduced Section	Normal Section	Reduced Section	Normal Section	Reduced Section
Minimum width (m)	60,00	45,00	34,00	30,00	24,00	18,00	14,00	11,00
Minimum vehicle range (m)	37,80	33,00	21,00	19,00	16,00	12,00	9,00	7,00
Minimum sidewalk (m)	5,00	3,00	4,00	3,50	3,25	3,00	2,50	2,0
Minimum central sidewalk (m)	9,00	4,00	5,00	4,00	1,50	-	-	-
Maximum slope (%)	6%	6%	8%	8%	10%	10%	15%	15%
Minimum slope (%)	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%

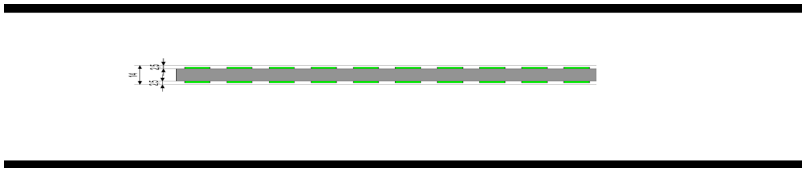
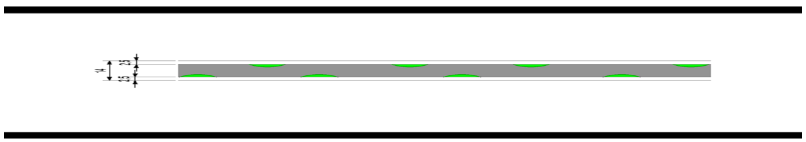
Source:Land Use and Occupancy Law (2017 page 51)

This research has proposed a pattern of BMP distribution based on dimensions determined by Land's Use and Occupation Law (LUOS, 2017) for different street categories from Fortaleza's road system. The proposition is according to the available space, without harming pedestrians or vehicles movement.

The 100m extension was defined to perform a comparative analysis of the retention capacity of Best Management Practices in different corridor patterns (Chart 4).

Chart 4 - Sizing of the BMP area applied in the road system

<table>
<tr><th>BMP APPLIED IN THE ROAD SYSTEM</th><th>BMP AREA (m^2) each 100m</th></tr>
<tr><td colspan="2">BIOSWALE</td></tr>
<tr><td>
</td><td rowspan="2">1500m^2 - expressway
500m^2 - arterial rout</td></tr>
<tr><td>Indicated for roads with generous beds where performance is better, the minimum width established was 3 meters and therefore, in this study, its application is restricted to express and arterial roads.</td></tr>
<tr><td colspan="2">RAIN GARDEN</td></tr>
<tr><td>
</td><td rowspan="2">280m^2</td></tr>
<tr><td>The raingardenshavebeendesignedwithatleast14m^2(2mmaximumwidthby7m minimum length), so do not get into local streets where the sidewalk can have at least 2 or 2.50 meters (LUOS, 2017). The proposed model provides access to lots for vehicles and pedestrians</td></tr>
</table>

RAIN FLOWERBED	
	120m^2
Because it is a rain garden with a reduced size, its size was 6m^2 (6m long by 1m maximum width). The proposed model provides access to lots for vehicles and pedestrians.	
CURB EXTENTION	
	80m^2
The curb extension has10m^2 and applies only to collector and local roads, the arterial and expressways can not include this type of speed control. The proposed model provides access to lots for vehicles and pedestrians.	
PERVIOUS PAVEMENT	
Indicated for application only to the walks of all types of roads	Variable

Source: prepared by the author

This research has calculated rainwater volume considering the BMP areas above presented. This analysis has considered the worst situation, adopting 100% for runoff. Below is the information about adopted data:

- Runoff Coefficient - 1. (ARAÚJO, 2005)
- 10-year return time for 65.2 mm / h (Δp) peak flow (SILVA; PALÁCIO JÚNIOR; CAMPOS, 2013).
- Corridor extension – 100 m

As the routes have different widths, evidently the precipitated volume (V) varied according to each typology (Table 3).

Table 3 - Area of tracks per 100m and volume precipitated

Road	AREA (m^2)	Precipitation Volume (m^2)
Local (L=14m)	1400m^2 (14x100)	91,28m^2
Coletora (L=24m)	2400m^2 (24x100)	156,48m^2
ARTERIAL (L=34m)	3400m^2 (34x100)	221,68m^2
EXPRESSA (L=60m)	6000m^2 (60x100)	391,2m^2

Source: authored by the author

From the calculation of the total precipitated volume and the definition of BMP areas per 100m corridor, it was possible to evaluate the performance of each technique in the different corridors of the Fortaleza road system. Moura (2013) indicates that the retention capacity of 1,00m² of rainforest equals a volume of 0,487m² (Vr / m²), this number is based on the values of the zero crushed porosity and the hydraulic macadam for a garden of rain of 1.00m². For the permeable floor the retention volume is 0.0945m² (Vr / m²) (MOURA, 2013).

4 Results

Table 4 below presents the results of the retention capacity of rainwater management techniques on express, arterial, collector and local roads (Table 4).

Table 4 - Evaluation of the BMP performance applied in the road system

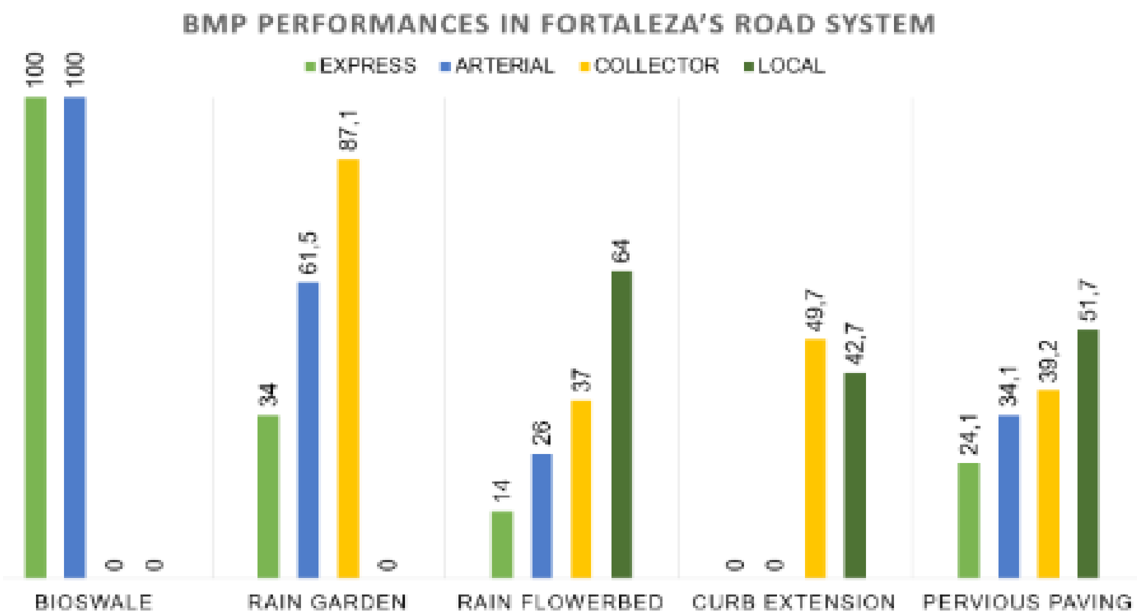
Road type	BMP AREA (m□)	Vr/m□(m□)	Retention Volume (m□)	Capacity %
	Bioswale			
Express	1500	0,487	730,5	186%
Arterial	500	0,487	243,5	109%
Collector	*	0,487	-	-
Local	*	0,487	-	-
	Rain Garden			
Express	280	0,487	136,36	34%
Arterial	280	0,487	136,36	61,5%
Collector	280	0,487	136,36	87,1%
Local	*	0,487	-	-
	Rain Flowerbed			
Express	120	0,487	58,44	14%
Arterial	120	0,487	58,44	26%
Collector	120	0,487	58,44	37%
Local	120	0,487	58,44	64%

	Curb Extension			
Express	**	0,487	-	-
Arterial	**	0,487	-	-
Collector	160	0,487	77,92	49,7%
Local	80	0,487	38,96	42,7%
	Pervious Pavement			
Express	1000	0,0945	94,50	24,1%
Arterial	800	0,0945	75,60	34,1%
Collector	650	0,0945	61,42	39,2%
Local	500	0,0945	47,25	51,7%
	Tree boxes			
	Note: The afforestation is considered in this research as a versatile BMP that can be integrated to all types of roads. Its retention capacity depends on botanical characteristics that will not be discussed in this analysis.			
	* The bioswales proposed in this analysis have a minimum width of 3m, so there is no room for application in the collecting and local pathways. ** Curbs extension are applied to promote traffic calm (BONZI, 2015), so do not apply in arterial and expressways that are characterized by the intense flow of vehicles.			

Source: authored by the author

The results of this evaluation demonstrate that the performance of Best Management Practices varies according to the hierarchy of routes. Four of thefive techniques present better performance in smaller corridors, collector streets and local ones (Graph 1).

Graph 1 - Performance of BMP in Road System



Source: prepared by the author

5 Data Evaluation

In order to classify the best combinations between BMP and roads for bioretention rainwater, this study has suggested three evaluation levels: Regular, Regular - Satisfactory and Satisfactory – Excellent (Table 5).

Regular: in this situation the BMP performance are below 35%. Therefore, the most efficient combination is better.

Regular - Satisfactory: they are favourable combinations that bioretention can reach 70% of the rainwater volume.

Satisfactory – Excellent: scenario where BMP can exceed 100% retention of the precipitated volume, functioning as a backup for atypical events, ie during an intense storm or at a time of failure of the conventional drainage system.

Table 5 - Performance rating of BMP applied in the road system

BMPs performance classification	
Regular	0 – 35%
Regular - Satisfactory	35,1 – 70%
Satisfactory - Excellent	Above 70%

Source: prepared by the author

Point out that any of the situations is favorable, regular performance does not mean that BMP application should be discarded, since its presence, even small, provides important environmental services. The rainforest, for example, can be applied in any corridor, but its limited space disrupts its performance in express avenues that have larger dimensions. This justifies its applicability in local and narrow streets, where its performance is more efficient in the retention of precipitated volume.

The classification suggested in Table 5 supports the definition of the most efficient combinations between the Best Management Practices and the typologies of routes, that is, in which types of corridors the management techniques have greater capacity of retention. Therefore, those that had a performance classified as regular were not recommended (Table 6), except for permeable tread for the arterial route that was very close to 35%.

Table 6 - Combination of BMP and road types discriminated by LUOS

BMP	ROADS TYPES			
	EXPRESS	ARTERIAL	COLLECTOR	LOCAL
BIOSWALE			X	X
RAINGARDEN	X			X
RAIN FLOWERBED	X	X		
CURB EXTENSION	X	X		
PERVIOUS PAVING	X			
TREE BOX				
Recomended X Not recomended				

Source: by the author

6 Conclusion

From the classification presented in Table 6 it is possible to conclude that:

- Rain flowerbeds and curbs extesion are indicated for smaller roads, since they fit the spaces of sidewalks and narrower streets, playing a satisfactory role in the retention of the runoff and contributing to the control of traffic in residential local routes.
- Rain gardens can be applied to collector and arterial roads,these should be part of the landscape of commercial corridors and services, encompassing a larger area of influence and playing an important role in controlling flooding points that hinder mobility in these avenues.
- Bioswales should contribute to the capture and transport of surface runoff on expressways characterized by wide sidewalks and central beds, which carry this type of BMP. Its application can promote the increase of green areas creating a permeable corridor that integrates different districts of the city.

Pervious paving are an important complement to increase the runoff bioretention, especially in densely built areas where it is necessary to apply solutions in order to increase the permeability rate.

The tree boxes represent the most flexible solution where there is no possibility to propose the other rainwater management techniques; trees play a key role in the environmental comfort of corridors through the composition of shaded and pleasant walkways for people.

The guidelines proposed above for BMP application in the road system allow the consolidation of Greenways in multiple scales, from the local streets of a small housing complex until an extensive avenue that crosses the city. Through these corridors, important green areas of the city can be connected by consolidating a Green Infrastructure. The connectivity between parks, squares and lagoons, promoted by mobility corridors adapted to the Best Management Practices, is essential for the constitution of a resilient city and for the accomplishment of ecological services.

In order to put this proposal into practice, further development is essential in the form of specific projects consonant with the physical and socio-economic characteristics of the mobility corridors. Ideally, these guidelines could be incorporated into legislation and urban plans, which admit mobility corridors as important parts of the city's urban development.

The transformations inherent in management techniques go beyond water retention and allow for landscape enhancement with the creation of green areas in streets and avenues forming corridors of integration between squares and parks. The possibility of establishing gardens in the streets would increase the public policies of valorization of vegetated and wooded spaces; the plaza adoption program could be expanded to adopt streets, or simply a garden.

Finally, Green Infrastructure is able to prevent, through its regulatory properties, the negative impacts on natural resources caused by urban growth and grey infrastructure. The Green Infrastructure in Fortaleza, consolidated through the Greenways would effect environmental and urban quality, with improved rainwater drainage and the creation of microclimates, favoring the city's resilience and offering a better quality of life. .

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