Green Roofs: Manual structure proposed for Brazilian cities

Priscila Nakamura
Federal University of Mato Grosso do Sul, Engineering, Architecture and Urbanism and Geography College (FAENG), Campo Grande (MS), Brazil
prinakk@gmail.com

Andrea Naguissa Yuba
Federal University of Mato Grosso do Sul, Engineering, Architecture and Urbanism and Geography College (FAENG), Campo Grande (MS), Brazil
naguissa@gmail.com

ABSTRACT: Regarding green roofs, policies and encouragement strategies have been adopted for more than thirty years in countries such as Germany, Switzerland, Japan and Canada, where there are supportive standards, guidelines and manuals. In Brazil, this issue is recent and several laws are being proposed in recent years, but they are superficial and do not show strong technical or scientific basis. This work aims to create the content of a manual, including design, construction and maintenance of green roofs systems for Brazilian cities, being Campo Grande, a city in Mato Grosso do Sul State, in Brazil, the study case. It is addressed to project designers, manufacturers, contractors and users, as a support for the implementation of constructive solutions. The city characteristics were described, the nomenclature of the material (guide or manual) was defined, and then Brazilian laws were evaluated, as well as guides and manuals in use. All the documents vary both in content and depth. Thus, it was defined the content of the manual proposed (script), that will be filled in the next step. The manual structure can be used in other sites with similar characteristics.

Keywords *green roof. manual. guide. public policy.*

ISBN: 978-85-92631-00-0

1. INTRODUCTION

Nowadays, green roofs are an important element for the transformation of the larger cities, as they contribute for the good performance of buildings and for the life quality of its inhabitants, creating more sustainable urban environments (Raposo, 2013). To achieve the full potential of green roofs, good planning process for proper construction is necessary and also the knowhow about how to take care the system through life time.

Some guides, manuals and documents with guidelines and requirements for construction, were developed first in Europe, where researches on green roofs started three decades ago. In Germany, where were born the modern green roofs systems (Magill et al, 2011), the natural resources scarcity and the population high density, forced people to develop sustainability practices in almost all economic activities (Buehler et al, 2011). By 1980 the consumer market of these roofs quickly expanded and according to Hui (2010), when the "boom" occurred, many of not qualified enterprises have emerged, creating a bad legacy of poorly built green roofs. This situation motivated the development of guidelines and standards, supported by research groups in universities. The FLL guide (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau - Research for the Development of Landscape, 2008), took seven years of a research team and became a reference worldwide. In 1996, at least 10 million square meters of green roof had already been built in Germany. It is important to note that State and Municipal Government laws, through financial bonus, stimulated this growth. Other European states and cities have adopted similar support strategies and policies, encouraging a new industry to provide vegetation, materials, contractors, and maintenance staff, among others.

In Brazil, laws to stimulate green roofs construction are being proposed in many cities, but these laws are quite superficial, with lack of knowledge. It is time to have some research improvements about green roofs in Brazil to prevent what happened in Germany, and especially for hottest regions. The documents available are guides, manuals, codes, and handbooks, from many countries. Despite the characteristics of the building sites (climate, vegetation, culture) the organization of each document has differences in approach, content, in-depth level, language, which were explored in Nakamura and Yuba (2016), and can be used to develop a Brazilian manual, non-existent yet.

2. OBJECTIVE

This study aims to define the content and structure for a Brazilian green roofs manual, addressed to designers, manufacturers, contractors and users, to give them the initial support to implement the construction system in Brazilian cities.

3. METHOD

Unlike Germany, Brazil has a greater territory, with different climates and vegetation. This sets different priorities for each region. To avoid generalizations that could become an obstacle to the assimilation of the proposed guide and also to enable this first approach, it was defined a study case.

ISBN: 978-85-92631-00-0

Thus, the city of Campo Grande, in Mato Grosso do Sul State, Brazil, was chosen because of easiness to obtain data about the city and vegetation, and also because of its warm climate. The strategies to this city can be generalized to other cities with similar characteristics.

Then, to define the structure of the manual, the following steps were carried out:

- Characterization of the city to elect priorities/ relevant topics;
- Definition of the nomenclature - guide or manual;
- Evaluation of content demanded in regulations;
- Evaluation of the content presented in the 4 documents and their origins, based on the results presented in Nakamura and Yuba (2016). These documents were chosen based on relevance, up-to-dateness, availability and location diversity (Europe, North America, Oceania and Asia). Thus, the German (FLL, 2008), Canadian (Touderlund, 2010), Australian (Environa Studio, 2010) and Chinese (Hui, 2011) guides were chosen. And also Raposo master's dissertation (2013) was a reference. This one presents guidelines for green roofs in Portugal, and it is very similar to what is being proposed;
- The way that the content is delivered to the reader;
- Definition of the structure and the content of the manual.

4. RESULTS

4.1 Climatic and vegetation characterization of the city:

According to Raposo (2013), one of the most important aspects in the design of green roofs concerns the weather conditions of the location, that influence directly on system performance through its lifetime. It plays a key role in the design process and in the definition of solutions. The main parameters to be considered are: temperature, rainfall and wind speed. These data interfere in the substrates selection and vegetation. However, water management and wind protection may help to overcome inhospitable environments.

Campo Grande city has 8092.95 square kilometers, and it is located in the central portion of the State (2.26 % of the total area of the State). Located in the geographical coordinates 20°26'34" south latitude and 54°38'47" west longitude, and the altitude varies between 500 and 675 meters. According to the socioeconomic profile of Campo Grande (PLANURB, 2015), the municipality has a high level of urbanization (98.66 %), an urban area of 35,903.53 hectares and a population density of 21.93 hab/ha, while in the city center has 2011.50 hectares and density of 35.32 hab/ha.

4.1.1 Winds

The stronger winds occur from June to October. In September occurs the highest wind speeds (77.32 km/h) and during October has the highest average speeds (14.98 km/h). The winds from northwest-east, northwest-northeast, northwest-north, north-east and north-northwest, occur during the whole year. Between 2009 and 2013, the north quadrant direction was the most recorded.

ISBN: 978-85-92631-00-0

4.1.2 Temperature

According to the Environmental Assessment Report (GROEN, 2015), the State is in a confluence zone of air masses that blow in Brazilian territory. The region sits in a climate transition area, resulting in severe thermal contrasts, those can happen during different time of the year, as well as in different places. According to INMET, the average annual temperature was 22.8^{0}C, while the maximum temperature occurred in October, February and November, reaching 31^{0}C. The minimum temperature was 14.7^{0}C and occurred in July. The thermal range in the region was 16.1^{0}C.

4.1.3 Rainfall

According to the Environmental Assessment Report (GROEN, 2015), from 2004 to 2015, the Center-West Region has the rainy season in the summer, from December to March. According to the atlas multireferential of Mato Grosso do Sul, Campo Grande is classified as humid and sub-humid climate, presenting annual rainfall between 1500 and 1750 mm, with an water surplus between 800-1200 mm during 5 to 6 months and water scarcity 350-500 mm during 4 months.

4.1.2 Vegetation

According to the Environmental Assessment Report (GROEN, 2015), Mato Grosso do Sul State presents phytogeography connexion with Chaco, Cerrado, Amazonia and Atlantic Forest. The city of Campo Grande is located in the Neotropical zone, in the Cerrado area. It presents a phitophisiognomy like Campo Limpo, Campo Sujo, Cerradão, besides the presence of Alluvial Forest, areas of ecological tension represented by the contact of Cerrado/Semidecidual Stational Forest and areas of anthropic formation, used for agribusiness.

Cerrado occupies 23% of the Brazilian territory, being the second largest in area and third in biodiversity. This area is occupied by a complex of vegetation that includes different physiognomies, resulted first due to fire or the distribution of soil types, or by the combination of factors such as climate, soil, water and nutrients availability, geomorphology and topography, latitudes, cattle raising and human activities impact. It also presents biological richness once it presents about 6000 species, 800 bird's species, besides a large variety of fishes and others. As the Atlantic Forest, it is one of the richest and threatened biome in the planet, and the Brazilian biome that suffered most changes by human actions. Actually, there is just 20.7% of the remaining vegetation in the city.

4.2 Guide or manual: expected product

One of the differences among the guides and manuals used as references was the format of the document. The German one is entitled as a guide (Guidelines for the Planning, Construction and Maintenance of Green Roofing), as well as the Hong Kong one (Technical Guidelines for Green Roofs Systems in Hong Kong). The Australian document is named as a manual (Green Roof Resource Manual) and the Canadian, in its turn, merges the two formats (Design Guidelines and Maintenance Manual for Green Roofs in the Semi- Arid and Arid West).

ISBN: 978-85-92631-00-0

The etymology of the words "guide" and "manual", does not present any meaningful differences. The analysis of the guides and manuals from different countries suggest that the material with less technical information were called "manual". On the other hand, the elaborated materials, with more technical information, and detailed content, were presented as a "guide". Therefore, following these examples, the content intended to be presented approaches more to the “manual” format**.** In the future, the manual may evolve to a “guide”, like the German one.

4.3 Content required by regulation

According to Raposo (2013), air quality, climate change, water supply, soil protection, biodiversity and natural landscape has public protection. These natural resources are irreplaceable in terms of quality of life and urban environment but not always are properly protected. Due to the green roofs cost/benefit relation and their importance to the more sustainable cities development, authorities from different countries (such as Germany, Switzerland, the UK, the US and Japan), started to adopt policies to stimulate green roof implementation, in order to promote the fast expansion of this market.

These strategies are being implemented with financial bonus, tax reduction on rainwater management, environment protection strategies and regulatory measures of urban planning and buildings construction (Raposo, 2013). In Toronto, Canada, the city code requires green roofs for commercial, institutional and residential buildings over 2.000m^2 of built area. Smaller buildings owners may join the city program, which since 2009 has helped to finance the green roof system installation.

In Brazil, recent several bills to stimulate the construction of green roofs were been proposed. In Campo Grande, the Law 5591 of 07.28.2015, addresses the construction of green roofs in public buildings. Moreover, it is still a bill, and it has to be submitted to a technical detailing. When compared to foreign laws, it is evident that it is technically imprecise, for example when it recommends to use less water to irrigate to prevent *Aedes Aegypti* mosquito habitat. Another weak point is to recognize green roof as a standard permeable area.

Therefore, in order to improve this law, other cities experience should be used. So green roof could become more trustable by users, contractors, manufacturers, designers and others.

4.4 Frequent content and their origin

An analysis of selected documents found recurring and fundamental contents for the composition of a manual about green roofs, as well as specific content that may or may not be relevant for the Brazilian cities manual. Table 1 shows the similar contents of the analyzed guides.

ISBN: 978-85-92631-00-0

Table 1. Recurrent content found in green roofs guides and manuals. Source: The authors (2016).

Recurring contents
Definition of green roofs
Goal of the guide
Guides and existent laws
Benefits of green roofs systems
Types of green roofs
Applicability range of green roofs (weather conditions)
Function and benefits of green roofs
Implications of loadings on the structure
Roof inclination
Architectural and executive roof project and adaptations (remodeling)
Cost considerations
Leaking detection
Waterproofing of the basis for green roofs
Protection against root penetration
Drainage (drains and pipes)
Water retention for vegetation
Water storage for multipurpose uses
Water filtration (draining blankets)
Substrate role and composition
Vegetation selection
Planting forms
Aptitude for agriculture and food production
Protection against accidents/security mechanisms
Wind action
Erosion protection
Fire protection
Integration of solar panels and other technologies on green roofs
Irrigation
Fertilization
Conservation and maintenance

*the highlighted topic means that the authors do not agree that it is essential to build a green roof.

All contents indicated above are relevant for Brazilian context, but the "integration of solar panels and other technologies" (highlighted), can be excluded, because their absences do not impact the viability of green roof.

Below are listed punctual contents, presented in one of them or in some of the analyzed documents. All subjects of the Table 2 are relevant, but not all of them are priorities. Users safety and health items were considered relevant and priority (highlighted), like the compatibility among the materials, because when it is made in a right way, it can increase the durability of the system, otherwise, it can result in gases emission, and pollution.

These particular issues could be named as secondary items, but they can define the success or failure of a large-scale initiative. Other content such as the "installation of furniture" and "aptitude for environmental certification", are considered relevant, but not priority to compose the structure, once they are additional issues, which can be developed later.

ISBN: 978-85-92631-00-0

Table 2. Specific content identified in the green roofs guides and manuals. Source: the authors (2016).

Specific content
Barriers/obstacles to the green roofs implementation
Aptitude for environmental certification
Compatibility among materials
Environmental compatibility (leaching emissions, disposal/recycling, pollution)
Tolerance levels of plants, phytotoxicity
Role of professionals
Protection against landslides and shear of green roofs
Construction elements (made locally or pre-fabricated)
Path ways on green roofs
Furniture installation (pergolas, trellises, lighting, etc.)
Caring for the installation of mechanical protection for waterproofing
Project management (production, administrative and legal context)
Warranties
Tests and inspections

It is important to emphasize the origin of the guides and manuals analyzed. The Hong Kong guide (Hui, 2011) and Canada one (Touderlund, 2010) were developed by researches in universities. The Canadian research had the collaboration of environmental organizations and the government. The Australian manual was prepared by government initiative, aiming to provide the community a new source of information, such as regulations, buildings certification, among others, and had the participation of six consultants and city representatives. The German guide was also prepared by various consultants from a group that supplies not only green roofs guidelines, but building systems guidelines in general.

The depth and coverage of each guide or manual is directly related to the number and diversity of professionals involved in preparing such material.

4.5 How to transmit the information to the reader

The manual script, i.e. the order of the contents, was based on two studies: Hui (2010) who proposes a better organization to separate and define the steps of the guide, and Raposo (2013), which presents a coherent sequence in order to facilitate search and understanding. Hui's approach (2010) drew attention to the items shown in Table 2. The author says that the stakeholders play a significant role to produce a guide, and emphasizes training and education to improve the understanding and skills in the development of the project, and its management. It shows how important are parallel actions to the manual creation, to deal with different aspects of the diffusion process.

4.6 Structure and content of the proposed manual

Using as the main reference Hong Kong guide (Hui, 2010), this manual was divided in three parts. The following scheme shows the proposed content for such manual:

- Part 1:
    - Introduction
    - Green roofs and its characteristics
    - Where the manual can be used

ISBN: 978-85-92631-00-0

- Part 2:
    - Design and construction
    - Management and maintenance
- Part 3:
    - Finals considerations
    - References
    - Appendix and/or attachments (if available)

Tables 3 and 4 show the steps and outline the questions to be answered in the next stage of the research. The content of part 1 is composed by an introduction, common to all the guides and manuals used as references, containing definitions, types of green roof and its benefits. It also introduces the sites where the manual can be used, based on Raposo (2013) considerations.

Table 3. Composition of the first part of the manual. Source: The authors (2016).

Part 1 (generals aspects)	Should contain
Introduction	---
Purpose	Objective of the manual
Guides and manuals in use	International examples
Benefits and barriers	Reference authors
Green roof and its characteristics	---
Definition	What is green roof? (Reference guides, authors)
Types	Describe the extensive, semi-intensive and intensive vegetation
Functional layers	Scheme of green roof structure, compatibility among the materials
Where the manual can be used	Mentions the extents of the manual
Campo Grande and its characteristics	Characterization of Campo Grande (Planurb, Inpe, Inmet...)
Climate	Show data (Planurb, Inpe, Inmet...)
Temperature	Show data (Planurb, Inpe, Inmet...)
Wind	Show data (Planurb, Inpe, Inmet...)
Vegetation	Characterization of Cerrado

Part 2 is composed by the most relevant factors for the implementation of green roofs. This part appears in the majority of the guides and manuals used as references. The construction steps will be shown, organized by themes (safety, rain, water management etc). Besides the items in common in all references, some punctual information was added. This information is relevant due to the specialized professionals involvement, as showed by Hui (2010).

ISBN: 978-85-92631-00-0

Table 4. Composition of the second part of the manual. Source: the authors (2016).

Part 2 (process of implementation)	Should contain
Design, viability and construction	**---**
Initial considerations	---
Objective	What is the destination of the green roof?
Budget	Address the final cost estimate
Accessibility	Who can access the roof?
Role of practitioners	Which practitioners are involved?
Analysis and choice of location	---
Load implications on the structures	Care with the load on a new or existent structure
Roof inclination	Values, search for the references
Wind action	Reference guides, search for acceptable wind speed values
Safety	---
Fall protection	Protection for contractors and users
Fire prevention	Measures that can help to prevent or control, references
Protection against shear and landslides	Measures to prevent accidents
Tightness	---
Waterproofing	Existing types in Brazil and the best ones for green roofs
Mechanical protection	Function, types of materials and installation methods
Root barrier	Existing types in Brazil and the best ones for green roof
Rainwater Management	---
Water drainage system (drains and pipes)	Function, types of materials and installation methods
Retention of water for vegetation	Function, types of materials
Water storage for multipurpose use	How can be done and for what use?
Water filtration (draining blankets)	Function, types of materials and installation methods
Vegetation performance	---
Role and composition of the substrate	Function, types, selection requirements. Search information regarding the area
Vegetation selection	Types (herbs, grasses and others), selection criteria
Phytotoxicity tolerance level of vegetation	Measures to guarantee the vegetation survival
Vegetation recommended for green roofs in Campo Grande	Tamires Yule recommendations for native vegetation of the Brazilian Cerrado (also known as Brazilian savanna)
Planting forms	References
Aptitude for agriculture and food production	References, types of food that can be cultivated in Campo Grande
Irrigation	Function, types of materials and installation methods
Fertilization	How to use, frequency. References
Management and maintenance	**---**
Project management (productive, administrative and legal context)	References
Warranties	Analyze warranties of specialized companies
Conservation e maintenance	Maintenance plan
Tests and inspections	Function, types of materials and installation methods

ISBN: 978-85-92631-00-0

5. FINAL CONSIDERATIONS

This study created a content structure for a Brazilian manual of green roofs. It did not intend to solve all obstacles and barriers regarding implementation of green roofs in Brazilian cities. Moreover, it introduced useful content for designers, manufacturers, contractors and users, to guide and inform them about the requirements to design it. In order to make this research viable and due to limitations (researchers, time, resources), this work defined a specific context.

The organization in topics was generated by a structured analysis of four important documents. It can be viewed as a summary of the mains issues around green roofs. The development of the contents does not constitute part of this work. In fact, it will be done in the next step of the research. Moreover, it will be given emphasis to the public and private sectors involvement and to the creation of a practical and easy to use material.

REFERENCES

Aziz H. and Ismail Z. 2011. *Design Guideline for Sustainable Green Roof System*. IEEE Symposium on Business, Engineering and Industrial Applications (ISBEIA), Langkawi, Malaysia Legal Aspects in Built Environment Initiative Group.

Dvorak, B. 2011. Comparative analysis of green roof guidelines and standards in Europe and North America. *Journal of Green Building*, 6 (2): 170-191.

Environa studio. Sydney City Concil Green Roof Resource Manual, Sydney. 2010. Available at: http://www.cityofsydney.nsw.gov.au/. Accessed November 5, 2015.

Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL). Guidelines for the Planning, Construction and Maintenance of Green Roofing. 2008. Available at: http://www.fll.de/verbandsstruktur.html. Accessed June 5, 2015.

GROEN-Engenharia e Meio Ambiente LTDA. 2015. *Consultoria em meio ambiente*. Relatório de Avaliação Ambiental. Programa de Desenvolvimento Integrado do Município de Campo Grande/MS. Preliminar version. Available at: http://www.pmcg.ms.gov.br/SEGOV. Accessed May 16, 2016.

Hui, S. 2010. *Development of technical guidelines for green roof systems in Hong Kong*. Proceedings of Joint Symposium 2010 on Low Carbon High Performance Buildings; Hong Kong.

Hui, S. 2011. Technical guidelines for green roofs systems in Hong Kong. Available at: http://www.mech.hku.hk/bse/greenroof/HK_Green_Roof_Technical_Guidelines.pdf. Accessed May 1, 2015.

Instituto Municipal de Planejamento Urbano – PLANURB. 2015. Perfil Socioeconômico de Campo Grande/Instituto Municipal de Planejamento Urbano - PLANURB. 22ª ed. rev. Campo Grande.

Instituto Nacional de Meteorologia - INMET. 2015. *Normais Climatológicas do Brasil 1961-1990*. Available at: http://www.inmet.gov.br/portal/index.php?r=clima/normaisClimatologicas. Accessed May 16, 2016.

Nakamura P. e Yuba A. N. 2016. *Comparação entre guias de coberturas verdes*. In: XVI ENTAC: Encontro Nacional de Tecnologia do Ambiente Construído. São Paulo. Annals.

Raposo, F. 2013. *Manual de boas práticas de coberturas verdes*. Lisboa: Instituto Superior Técnico, Universidade de Lisboa. Master's dissertation.

Tolderlund L. 2010. Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West. Available at: http://www2.epa.gov/sites/production/files/documents/GreenRoofsSemiAridAridWest.pdf. Accessed November 5, 2015.