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# Green Roof as a Measure of Efficiency and Infrastructure in Urban Areas in the City of Recife, Pernambuco, Brazil

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*Keywords:* *quality of life; sustainability; green roof.*

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# Green Roof as a Measure of Efficiency and Infrastructure in Urban Areas in the City of Recife, Pernambuco, Brazil

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*Abstract-* The present work evaluated the applicability of the green roof system in the city of Recife after Municipal Law nº 18,112/2015. For this, a quantitative diagnosis of the architectural projects deferred with the green roof system from the period from January 13, 2015 to September 30, 2019 was carried out. With the data survey, a quantitative analysis was carried out making a relationship with the urban, social and environmental aspects of the region where they operate. It was possible to observe that the years 2016 and 2019 presented a greater quantity in the construction area with a green roof system approved by the Municipality of Recife, in the period from January 13, 2015 to September 30, 2019. In relation to the area of the green roof expected in these projects, 2019 was characterized by the largest available area, followed by 2016. The years 2015, 2017 and 2018 had smaller areas and their values did not differ statistically from each other. The number of projects differs from one period to another, being greater in the last two years of the survey. Within the scope of the territorial outline established by these Political-Administrative Regions, the data also demonstrate that the green roofs had greater representativeness, when analyzed under the quantitative aspect, in buildings of the multifamily type. It was also possible to verify that most of the projects are inserted in the agglomerations of vertical buildings, in areas of intermediate temperatures of 24ºC to 26ºC, with a predominance of higher values, in environs with few green areas available in their blocks and still in places with critical flooding problems. In general, the realization of this research allowed us to see, with the results obtained, that the green roof system is still little used in the city of Recife, indicating the need for the Government to adopt incentive measures, through tax deductions or subsidies, such as IPTU (city housing tax) reduction.

*Keywords: quality of life; sustainability; green roof.*

*Resumo-* O presente trabalho avaliou a aplicabilidade do sistema de telhado verde na cidade do Recife pós-Lei Municipal nº 18.112/2015. Para isto, foi realizado um diagnóstico quantitativo dos projetos de arquitetura deferidos com o sistema de telhado verde do período de 13 de janeiro de 2015 a 30 de setembro de 2019. Com o levantamento dos dados, efetuou-se uma análise quantitativa fazendo uma relação com os aspectos urbanísticos, sociais e ambientais da região onde estão inseridos. Foi possível observar que, os anos de 2016 e 2019 apresentaram maior quantidade em área de construção com sistema de telhado verde deferidos pela Prefeitura do Recife, no período de 13 de janeiro de 2015 a 30 de setembro de 2019. Já em relação à área de telhado verde prevista nesses empreendimentos, o ano de 2019 caracterizou-se por maior área disponível, seguido de 2016. Os anos de 2015, 2017 e 2018 tiveram menores áreas e os seus valores não diferiram estatisticamente entre si. A quantidade de projetos difere de um período para outro, sendo maior nos últimos dois anos do levantamento. No âmbito do recorte territorial estabelecido por essas Regiões Político-Administrativas, os dados demonstram também que os telhados verdes tiveram maior representatividade, quando analisados sob o aspecto quantitativo, nas construções do tipo habitacional multifamiliar. Também pôde-se constatar que a maioria dos projetos estão inseridos nas aglomerações de edificações verticalizadas, em áreas de temperaturas intermediárias de 24ºC a 26ºC, com predominância de valores mais altos, em bairros com poucas áreas verdes disponíveis em suas quadras e ainda em locais com problemas críticos de alagamentos. De uma maneira geral, a realização desta pesquisa permitiu visualizar com os resultados obtidos que o sistema de telhados verdes ainda é pouco utilizado na cidade do Recife, indicando a necessidade do Poder Público em adotar medidas de incentivos, através de deduções fiscais ou subvenções, como a utilização da redução do IPTU.

*Palavras-chave: qualidade de vida; sustentabilidade; telhado verde.*

## I. Introduction

With the intensification of the industrialization process in the middle of the 20th century, Brazil saw a strong transformation in its form of settlements with the migration of the population from rural to urban areas.

Due to the process of evolution of the guidelines related to the theme of sustainability and to the growing environmental and urban problems presented in the cities, there was the creation and approval of Municipal Law nº 18,112/2015 in the city of Recife, with the objective of contributing to the improvement of the environmental quality of buildings and their surroundings through the mandatory installation of a green roof (for multifamily housing buildings with more than four floors, and non-housing with more than 400 m² of covered area), and the construction of reservoirs to accumulate or delay the

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flow of rainwater into the drainage network (PREFEITURA DO RECIFE, 2015).

Given the relevance of implementing green roofs in urban centers and the need for their effective permanence in buildings, the importance of this research is justified by the fact that it intends to portray the impact of the aforementioned law in the city of Recife. The amount of information available on the demand for projects and construction of buildings after the law is practically null. It is sought, then, with this research, to minimize the existing academic and technical-scientific gap and to stimulate future studies on the theme.

Consequently, the article aims to evaluate the applicability of the green roof system in the city of Recife after Municipal Law nº 18,112/2015. Initially, it identifies, through flowcharts, the steps of the approval procedure of the architecture project with the City of Recife. It draws a quantitative diagnosis of the architectural projects approved with a green roof system after municipal law and presents a correlation of these projects with some urban and environmental aspects of the region where they are located.

## II. Bibliographic Reference

The urbanization process occurred quickly and in a disorderly manner, causing several environmental and urban problems, such as water, air and noise pollution, global warming, the formation of heat islands, an increase in the greenhouse effect, floods, increasing soil impermeability, vegetation suppression, among others, changing the quality of life in cities (KOZMHINSKY; PINHEIRO; EL-DEIR, 2016; RANGEL; ARANHA; SILVA, 2015).

During an attempt to preserve and restore what remains of natural resources, the world began, in 1970, to debate in international and national levels about the sustainable development of the planet. The formulation of concepts and documents to point out environmental strategies first appeared in the Brundtland Report in 1987, prepared by a Commission formed by industrialized countries, where sustainable development is conceived as the *development that meets present needs, without compromising the capacity of future generations to meet their own needs* (ROLA, 2008).

These concepts served as a theoretical basis for the preparation of various documents and national meetings such as ECO 92, held in Rio de Janeiro in 1992, which culminated in the creation of the Agenda 21 and the Statute of Cities governed by Federal Law No. 10.257/2001, proposing that each country should draw up its environmental preservation plan for the 21st century. From 1996 to 2002, the Brazilian government began to carry out extensive consultation with the population, resulting, in 2004, in the "Brazilian Agenda 21" document, structured in several objectives, showing, with regard to the sustainability of cities, guidelines for actions to guarantee the governance of the urban space by the metropolitan authority. The City Statute, at the municipal level, is considered a new legal framework for public policies, which, added to the Brazilian Agenda 21, provides Brazilian municipalities with basis for the construction of sustainable cities, making economic and social development compatible with the preservation of the environment (KOZMHINSKY; PINHEIRO; EL-DEIR, 2016; ROLA, 2008).

Moving forward on the agenda of initiatives to ensure sustainable development, the United Nations (UN) held a conference in New York between September 25 and 27 of 2015, outlining a new action agenda to be fulfilled by 2030, entitled "*Transforming Our World: the 2030 Agenda for Sustainable Development*", generating a Declaration that establishes 17 Sustainable Development Goals, supported by three basic pillars: improving people's living conditions, eradicating poverty, promoting prosperity and welfare for everyone, and protect the environment (GARCIA, D.; GARCIA, H., 2016).

The non-stopping actions in searching for new forms of planning, development of technologies and appropriate environmental solutions to guarantee the quality of life in cities, have led many countries to adopt public environmental policies that encourage the implantation of green roofs on the roofs of buildings (SHARMAN, 2014).

Thus, green roofs emerged as an alternative to compensate for the suppression of vegetation in the urbanization process, helping to solve problems in urban centers in relation to quality of life and the environment.

The system presents itself as a constructive technique characterized by a vegetal covering, consisting of grasses and/or plants, implanted in slabs or conventional roofs (RANGEL; ARANHA; SILVA, 2015). These public environmental policies initially started in Europe (in the second half of the 20th century, mainly in Germany), the United States and Canada, where several scientific studies on this emerging topic demonstrate that this technique has been frequently discussed, being in evidence worldwide (BERARDI; GHAFFARIAN HOSEINI; GHAFFARIAN HOSEINI, 2014; LUZ, 2017; RANGEL; ARANHA; SILVA, 2015; SETTA, 2017). Thus, at the end of the first decade of the 21st century, some Brazilian cities also began to create laws, providing tax incentives to the population, and creating other laws, establishing the mandatory installation of the green roof system in buildings (SETTA, 2017).

Visibility in Brazilian territory is due to its sustainable characteristics and the benefits presented, the main ones being: reduction of rainwater runoff (BALDESSAR, 2012; GETTER; ROWE; ANDRESEN, 2007; PINTO, 2014; PEREIRA, 2017; ROWE, 2011), reduction of greenhouse gases and urban heat islands

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(BALDESSAR, 2012; CATUZZO, 2013; PEREIRA, 2017; SCHMIDT, 2009), improvement of air quality (GETTER; ROWE, 2009; YANG; YU; GONG, 2008), improvement of rainwater quality (BERNDTSSON; EMILSSON; BENGTSSON, 2006; BORGA, 2012), reducing energy consumption and thermal comfort (JIM; TSANG, 2010; PINTO, 2014).

Among so many contributions, we still emphasize that depending on the proposed architectural project and the desired landscaping, green roofs have various uses, from small lawns, gardens, squares with leisure areas, even spaces for the cultivation of gardens, where the income generation presents itself as an innovative perspective in the use of vegetables, spices, ornamental and medicinal plants, fruit plants and even animals, being necessary to guarantee the integrity of the plants for their consumption and commercialization (ARAÚJO, 2007; GOMEZ; GAJA; REIG, 1998; OSMUNDSON, 1999).

The biggest obstacle to building a green roof is the high initial cost of implementation, depending on several factors, such as geographic location, roof type, size of the green roof, type of vegetation, qualified labor and correct materials to be used. Each green roof presents itself as a unique project (BIANCHINI; HEWAGE, 2012; PEREIRA, 2017). For the implementation of these roofs, it is necessary to use the services of professionals/specialized technical companies (in order to avoid structural problems, as well as leaks and infiltrations), which is one of the biggest problems of this practice, but every year companies specialized in the subject begin to introduce innovative products with specific technology and materials to the market (KOZMHINSKY; PINHEIRO; EL-DEIR, 2016).

Incentives for the implementation of green roofs in Brazilian cities through public environmental policies, as well as the dissemination of this system, are still slow. Only recently have some cities adopted laws to encourage the use of this technology. The promotion and dissemination of the use of sustainable technologies (such as green roofs) by the Government is essential, since it is co-responsible, together with the economic sector and society, for the preservation of the environment. (RANGEL; ARANHA; SILVA, 2015).

It is expected that this research can contribute to a better understanding of the impacts generated by the installation of green roofs in the city of Recife. This research still intends, based on the data obtained, to help stablish general guidelines and actions that should be promoted by the public management in the incentive for the maintenance of green coverings in this city and in the greater dissemination to make the population aware of the use of this technique.

## III. Material and Methods

This research is characterized by qualitative and quantitative, descriptive, empirical, cross-sectional analyzes. The study is based on the empirical-analytical method of an observational nature, consisting of the collection, treatment and more in-depth analysis of the data, without carrying out any type of intervention, which may interfere with the natural course of the study.

The research has taken place at the city of Recife, latitude 08° 03'15" South and longitude 34°52'53" West, capital of the state of Pernambuco, Brazil. A seaside town, with an approximate area of 218, 50 km$^2$, with an estimated population of 1.645.727 inhabitants (IBGE, 2019), all residents in urban areas, being the third most populous municipality in the Northeast and the ninth in the country.

The city is formed by a plain with islands, peninsulas, wetlands and mangroves, bathed by rivers, in the Central-East region and by hills, in the North, West and South, with high relative humidity, abundant rainfall during the year, humid tropical climate and average annual temperature of approximately 26° (and in summer around 30°).

The purpose of this study was to evaluate the applicability of the green roof system in the city of Recife, after the mandatory Municipal Law No. 18,112, of January 12, 2015. The research methodology was guided in four stages and the time horizon of this work was from January 13, 2015 to September 30, 2019.

Initially, from the data listed in Municipal Decrees No. 30,975 / 2017, with its changes validated in Decree No. 31,690 / 2018, flowcharts of the phases of the procedures for the approval of the architectural project with the City of Recife were produced, since the beginning of entry into the said agency until the final phase of the habit (certificate of authorization, issued by the City Hall, allowing the property to be occupied, attesting that it was built according to legal requirements).

In the second stage, the information in this study was obtained through documentary research, for data collection, identifying and quantifying the architectural projects with green roofs approved by the City of Recife, after the mandatory law, object of this study. Therefore, those prior to the law are not counted, nor are those that the law does not require mandatory.

The data collected through the architectural projects, located in the digital processes, electronically, in the period from 2017 to 2019, through the General Management of Geoprocessing and the Urbanistic Licensing Portal of the City of Recife, identified 87 projects with a green roof system, among the 284 deferred projects analyzed. As for the data of architectural projects, in physical environment, from 2015 to 2018, they were collected through a monograph by Mariana Aragão da Silva, entitled Analysis of



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Municipal Legislation nº 18,112/2015: a study of the implementation of green roofs as a strategy for sustainable construction in the city of Recife, Pernambuco, in the 06 (six) public archives of the 03 (three) Regional Divisions of the Prefecture of Recife, where 1,076 plants were analyzed that fit the prerogative of being approved from 2015, with 56 projects identified with green roofs (Appendices 1 and 2).

The work of Aragão (2020) aimed to analyze municipal legislation No. 18,112/2015, showing the advantages of using sustainable alternatives for construction, aiming at increasing the quality of life in cities, analyzing the items contained in the text of municipal legislation, checking of the implementation through the survey of the projects in the City of Recife and elaboration of a proposal with suggestions for improvements to incorporate the revision of the legislation, to be presented to the *Instituto da Cidade Pelópidas Silveira*.

In the third research phase, during the month of September 2019, a territorial cut was made, identifying through field research, the situations of the buildings in which the buildings with a green roofing system are found: constructions not started, those started and those completed with housing permit.

With all the surveys completed, the extracted data was processed and analyzed using descriptive and inferential statistical techniques, through the correlation and regression of the collected data, with the aid of the statistical software Statistical Package for the Social Sciences® (SPSS), version 24. The analyzes consisted of hypothesis testing and analysis of variance of the data collected, followed by a mean test for those that had significant results.

Concluding, with the elaboration of maps (with the aid of AutoCAD® 2011 software) identifying through the Geographic Information System of the Municipality of Recife - ESIg, the location of the deferred architecture projects with a green roof, based on the six Recife's Political-Administrative areas (RPA's).

It should also be noted that the maps and information presented here, such as green roofs, building belt stains and critical flooding points, were originated from several sources: *Instituto da Cidade Pelópidas Silveira* ICPS (2018), Recife's Master Plan - PDCR (2018), Urban Cleaning and Maintenance Company - EMLURB (2018).

## IV. Results and Discussion

*a) Approval procedures for architectural projects*

In order to facilitate the understanding of the implementation of green roofs in the city of Recife, flowcharts were created containing the procedures (made available electronically) for the application, processing and completion of the approval of architectural projects - based on the instructions defined in Municipal Decree nº 30.975/2017, with the changes validated in Decree nº 31.690/2018.

Emphasizing that all construction permits (as of December 4, 2017) and all projects (including architecture as of August 28, 2018) are now approved, exclusively through the digital urban planning process (PU) electronically, through the Urban Licensing Portal of the City of Recife. A construction permit or license is defined as: "Document, issued by the City Hall, of a license for the execution of a new work or renovation, based on the architectural project previously approved" (https://licenciamento.recife.pe.gov.br).

As stated in Decree No. 30,975/2017, initially all professionals and companies must register with the Integrated Urban Licensing System (SILUR), through the Licensing Portal, to enable the opening or monitoring of the digital process (PU). This opening will depend on validation, by the Licensing Center, within a maximum period of three calendar days, from the request, for the formalization of the process at SILUR, which flowchart is shown in Figure 01 (DECRETO Nº 30.975/2017).

If this validation is not approved, the process is automatically canceled, making it necessary to make a new request to restart the process. Once the opening has been approved, without any non-conformities, the Municipal Collection Document (DAM) is issued, when appropriate, for due payment, within fifteen consecutive days, from the issue of said document. If payment is not made within the stipulated period, the request will be automatically denied, and the entire opening application must be restarted.

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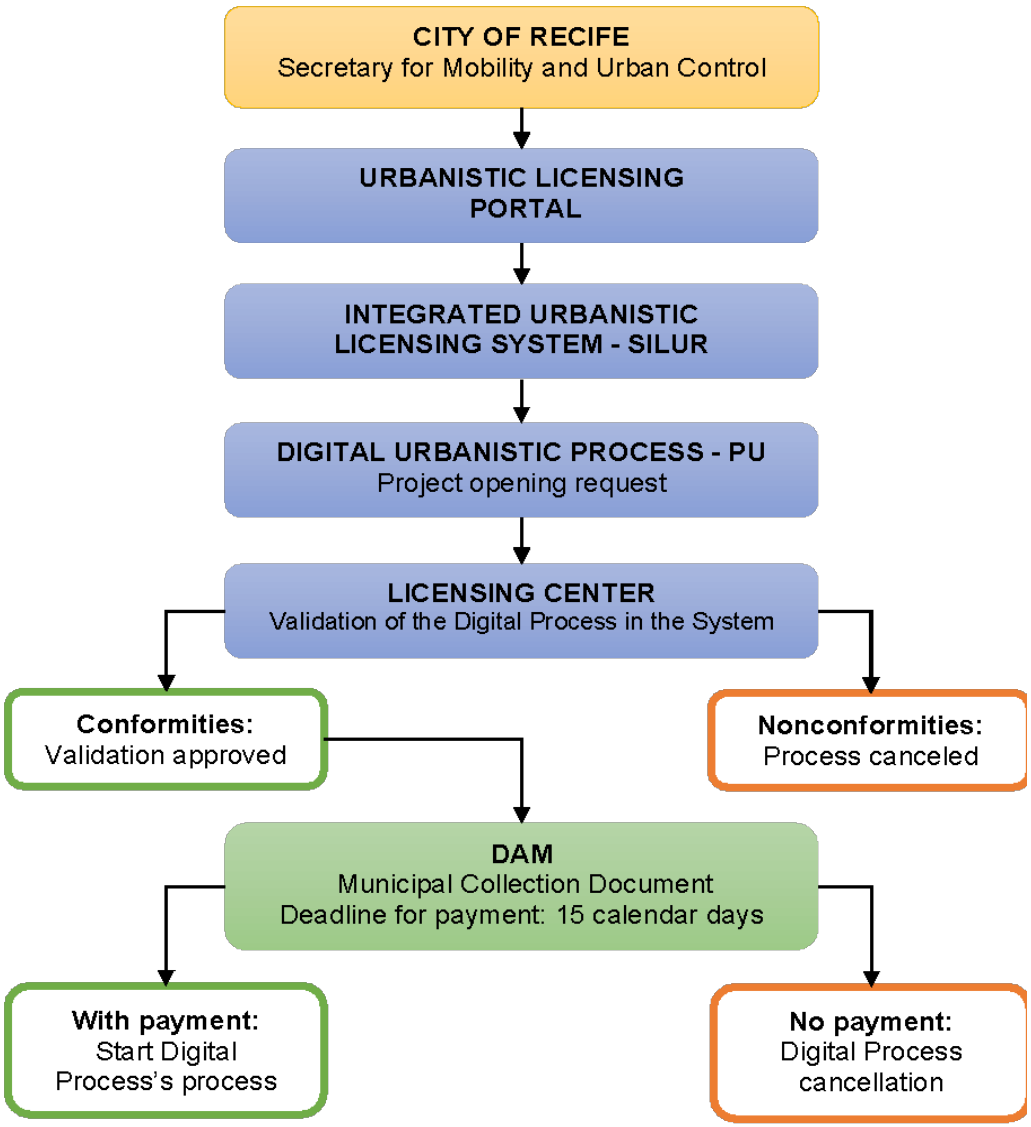


*Figure 1:* Flowchart of opening digital urban processes

With the opening of the validated digital process, it starts to be processed, through electronic referral, by the Regional Divisions, depending on the location of the environs where it is inserted. When applicable, it is sent to other external municipal units, which, after pronouncement, return to the Licensing Center, where the Head Office distributes it among the project analysts for technical analysis, according to the flowchart shown in Figure 02 (DECREE No. 30.975 / 2017; DECREE No. 31.690 / 2018).

After the payment of the DAM, the Licensing Center has a maximum period of 90 calendar days to complete the approval analysis or not of the process. Does not account for the time elapsed with the fulfillment of requirements by the applicant, with the analysis of bodies external to the Licensing Center, nor with operational problems caused in the electronic system.

In the event of rejection of the process, Decree No. 30,975 / 2017, stipulates the conditions and deadlines for compliance with the requirements. When the process is approved, the plans of the architectural project are available in the electronic system, containing the digital signature of the person responsible for approval. The validity period of the approved architecture project is 01 year, and you can request revalidation for the same period. Having the other complementary projects such as Works of Art, Fire Prevention and Fighting System, Waste Management and others, also already approved by electronic means, you can enter with a request to open a process for Construction Permit, exclusively, through electronic means.

After granting the Permit, it is no longer necessary to revalidate the architectural project, having a validity period of 01 year for works of up to 500 m$^2$ and



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03 years for over 500 m², which can be renewed for equal periods. The Flowchart in Figure 02 ends with the issuance of the Permit to Stay, where the City Hall attests that the building was built in accordance with legal requirements and the property is ready to be occupied.

Thus, this Permit is presented as an important tool of inspection and control of the Municipal Government to ensure that the construction takes place in order to ensure its structural, functional, aesthetic and its relationship with the external environment, providing an improvement in the quality of the built environment.

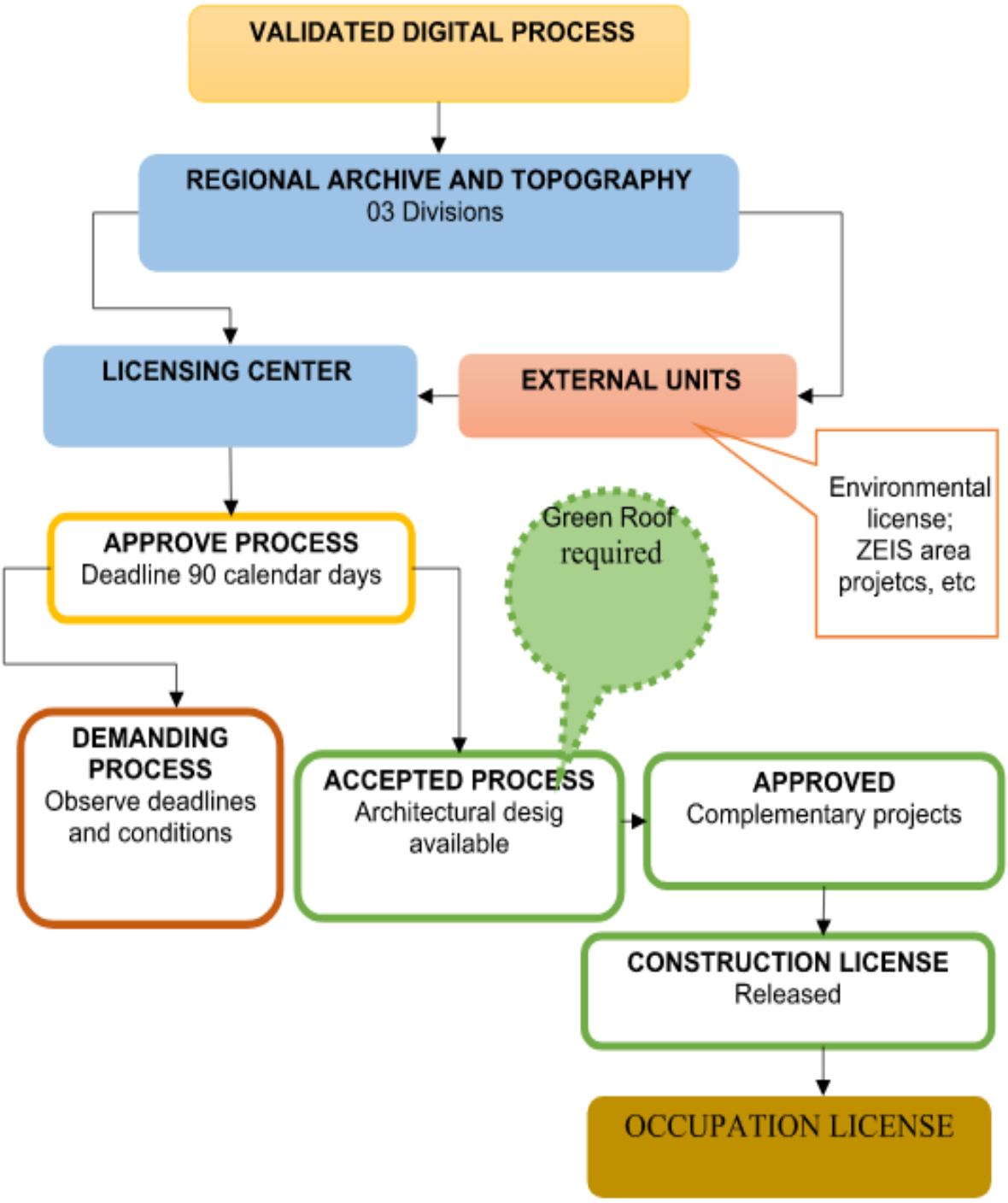


*Figure 2:* Flowchart of the digital architecture process



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*b) Analysis of survey data collection*

After analyzing the data collected, it was possible to observe that the years 2016 (557,231.94 $m^w$) and 2019 (641,150.18 $m^2$) were the ones that had the largest amount in construction area presented in the architectural projects, with a green roof system. , granted by the Recife City Hall, from January 13, 2015 to September 30, 2019, not statistically different from each other, compared to 2015 (214,654.36 $m^2$), 2017 (154,642.97 $m^2$) and 2018 (198,830, 54 $m^2$) that presented similar quantities to each other. In relation to the green roof area planned in these projects, 2019 (36,478.03 $m^2$) is characterized by the largest available area, followed by 2016 (20,657.08 $m^2$). The years 2015 (10,900.50 $m^2$), 2017 (8,849.33 $m^2$) and 2018 (11,508.39 $m^2$) had smaller areas and their values did not differ statistically from each other (Figure 03).

The 2015/2016 biennium characterized a period of severe recession in Brazil, immediately affecting civil construction, whose economic activity worsened with "Operation Lava-Jato" as it impacted the operations of national companies linked to this sector. In 2017, the beginning of the economic recovery was foreseen, however, the activity of civil construction remained very retracted and delayed in this recovery. In fact, it started showing signs of improvement from 2018 (TINOCO; GIAMBIAGI, 2018).

Intriguing factor in 2016, as it has a construction area of 557,231.94 $m^2$ in the midst of a recession in the country. It should be noted that in that year, 70% of the approved projects did not start construction until September 2019 (Tables 01 and 02) and that 20% only started to build in the 2018/2019 biennium (Table 02). As for the construction area found in 2019 in the research period between January and September of that year, the market is heating up in relation to civil construction activities, coupled with more in-depth knowledge of the legislation in force by architects, engineers and construction companies regarding the mandatory installation of a green roof.

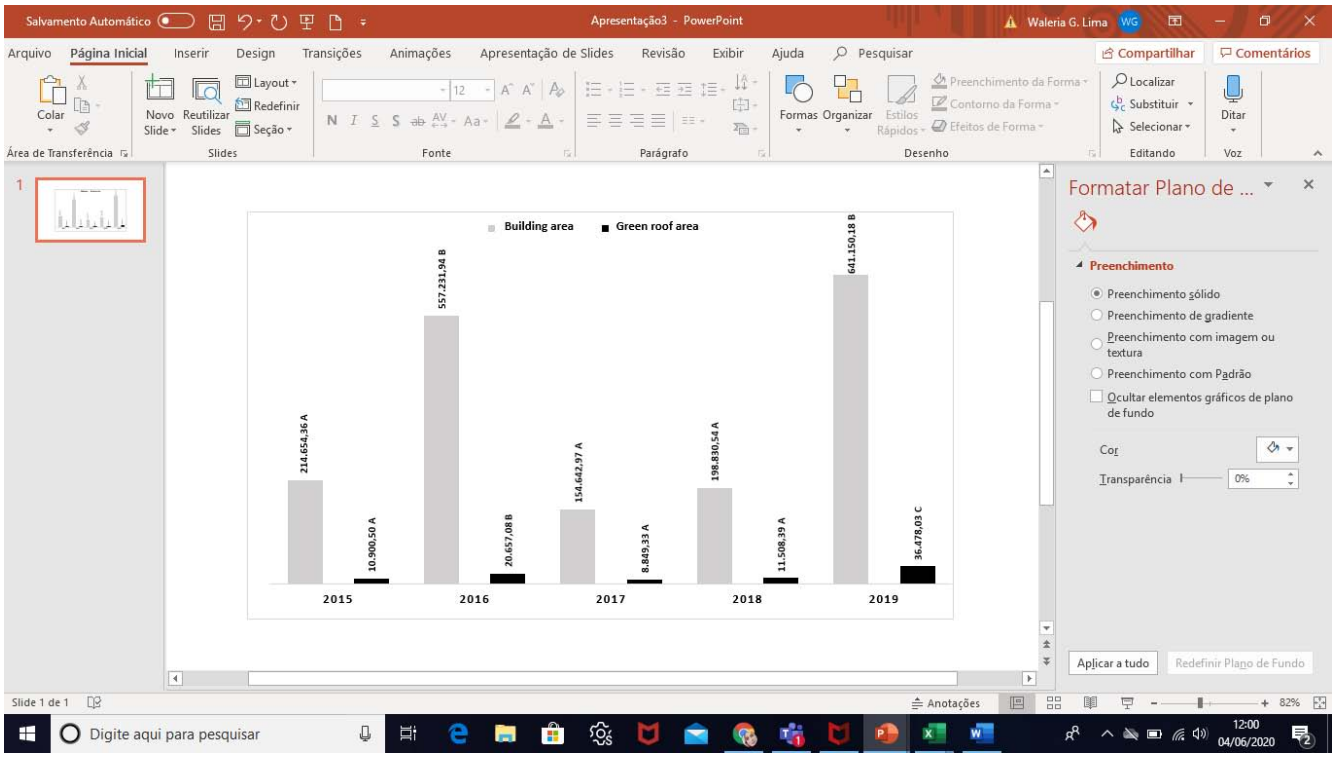


*Figure 3:* Expected areas of approved architecture projects with a green roof system, from January 2015 to September 2019, for the construction of projects (1,766,509.99 $m^2$) and green roofs (88,393.33 $m^2$) in the city of Recife. Averages followed by the same letter, do not differ, by the Tukey Test, at the level of 5% probability

Regarding the type of construction, among the 143 architectural projects surveyed with a green roof system, it was identified that the projects are built with three purposes of use: multifamily housing, non-housing and mixed. As for multifamily housing use, it was possible to observe that the number of developments has seen a significant increase over the years compared to other uses. The same was observed in relation to the total area of green roofs. However, mixed use presented similar building units for the years 2016 and 2019, although, in relation to the green roof area, 2016 (11,618.01 $m^2$) was higher than 2019 (2,680.09 $m^2$), which in turn, did not differed statistically from 2017 (2,029.60 $m^2$) (Table 01; Figure 04).



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*Table 1:* Number of projects and total area ($m^2$) of green roofs foreseen in the approved architecture projects from January 2015 to September 2019 in the city of Recife, depending on the type of use of the building. Averages followed by the same letter, do not differ, by the Tukey Test, at the level of 5% probability

| Type of Use | ear | Number of projects (units) | Total area of Green Roofs ($m^2$) |
|---|---|---|---|
| Multifamily Housing | 015 | 18 B | 8.403,35 B |
| | 016 | 11 A | 5.883,00 A |
| | 017 | 11 A | 6.355,73 A |
| | 018 | 24 B | 9.773,29 B |
| | 019 | 46 C | 25.023,80 C |
| Non-Housing | 015 | 3 A | 2.497,15 B |
| | 016 | 2 A | 3.156,07 B |
| | 017 | 1 A | 464,00 A |
| | 018 | 4 A | 1.341,21 B |
| | 019 | 7 B | 8.774,14 C |
| Housing and non-housing | 015 | 0 A | 0,00 A |
| | 016 | 7 B | 11.618,01 C |
| | 017 | 2 A | 2.029,60 B |
| | 018 | 1 A | 393,89 A |
| | 019 | 6 B | 2.680,09 B |

In the 1980s, the urban legislation of the city of Recife did not allow the avenues to build mixed-use typologies, that is, trade and services together with housing use. The residential areas were the ones with the highest coefficients of use on the land. Thus, commerce and some services preferred to renovate the existing single-family housing buildings for their facilities. In this way, real estate agents discouraged as to the construction of these developments, centralized their activities exclusively in the construction of verticalized multifamily housing and business centers (MEDINA, 1996). Added to this, the unrestrained occupation of the urban territory by the growing population, leading to the gradual replacement of single-family housing by multifamily.

As for Figure 04, it is also observed that the green roof area in the different construction types has been gradually increasing since 2017, except for the year 2016, which presents a peak in the mixed used area (11,618.01 $m^2$). A punctual case appears, considering that six large architectural projects were approved at the time, including only one of them being listed as a project started among the four listed in 2016 (Table 02).



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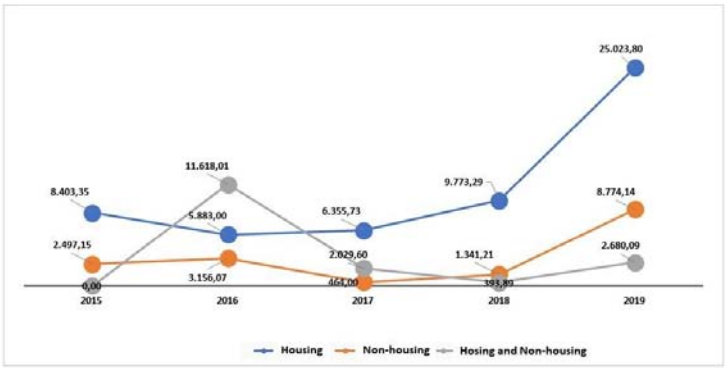


*Figure 4:* Areas, in m$^2$, of green roofs provided for in the approved architecture projects from January 2015 to September 2019 in the city of Recife, depending on the type of use of the building.

As shown in Table 02, the works entitled started, although presenting the architectural projects approved in intervals of years between 2015 and 2019, had the month of September 2019 as a research base in relation to the situation of the constructions, that is, of the 21 deferred projects, in 2015, 06 are live and 03 are with works started. In 2016, of the 20 projects, currently, 02 have housing and 04 have started works. For 2017, of the 14 approved projects, there are 01 with housing and 06 started. Still, in relation to the 29 projects in 2018, 01 has a home and 11 are under construction. While, until September 2019, of the 59 deferred projects, for the short period of time, none has yet to be settled, and 04 are started. Totaling, with the completion of the works, an area of 22,926.58 m$^2$ of available green roofs, improving the quality of life of the population of Recife (BALDESSAR, 2012; CATUZZO, 2013; PEREIRA, 2017; GETTER; ROWE, 2009; YANG; YU; GONG, 2008).

It is also noted that the units of enterprises in the works started in the years surveyed do not differ statistically from each other, with the exception of 2018, which shows a higher quantity, with 11 units, although, in relation to the green roof area, it is the year of 2019 (6,913.05 m$^2$) with the largest area, where in the years 2016 (3,007.19 m$^2$), 2017 (2,104.49 m$^2$) and 2018 (3,913.70 m$^2$) their values did not differ statistically from each other (Table 02).

*Table 2:* Number of projects and total area (m2) of green roofs in relation to the construction situation of the buildings in the city of Recife, based on the month of September 2019. Averages followed by the same letter, do not differ, according to the Tukey Test, at the 5% probability level

| Construction status in September 2019 | Year of architectural design approval | Number of projects (units) | Total area of Green Roofs (m$^2$) |
|---|---|---|---|
| Not started | 2015 | 12 B | 7.497,68 B |
| | 2016 | 14 B | 14.699,08 C |
| | 2017 | 7 A | 6.463,55 A |
| | 2018 | 17 B | 7.241,46 A |
| | 2019 | 55 C | 29.564,98 D |
| Started | 2015 | 3 A | 718,54 A |
| | 2016 | 4 A | 3.007,19 B |
| | 2017 | 6 A | 2.104,49 B |
| | 2018 | 11 B | 3.913,70 B |
| | 2019 | 4 A | 6.913,05 C |
| | 2015 | 6 B | 2.684,28 B |
| | 2016 | 2 A | 2.950,81 B |



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| | | | |
|---|---|---|---|
| Occupation License | 2017 | 1 A | 281,29 A |
| | 2018 | 1 A | 353,23 A |
| | 2019 | 0 A | 0,00 A |

In Figure 05, the impact of the financial crisis faced in the country in 2016 can be seen, with the civil construction activity soon being affected, demonstrated by the works not started this year, with a total area of green roof corresponding to 14,699.08 m$^2$. The information from the documentary and field research clearly portrays that the market started to react from 2018, where 55 new architectural projects were approved in 2019 with a green roof system (29,564.98 m$^2$), which for the most part still did not have enough time to start their construction and the four started will make available, at the end of the works, an area of 6,913.05 m$^2$ of green roofs, this quantity, not seen in previous years, nor in areas with habitation (Table 02; Figure 05).

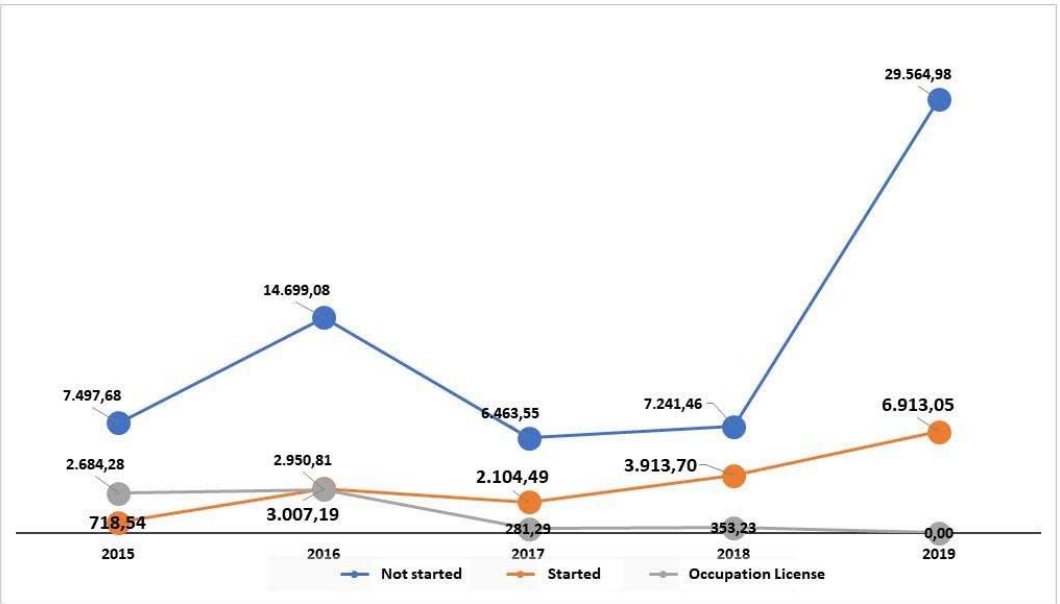


*Figure 5:* Areas, in m$^2$, of green roofs in relation to the construction situation of buildings in the city of Recife, based on the month of September 2019

As for the legality of the projects, these can be classified as mandatory, those that are within the scope of the law, and not mandatory, for those that the law does not require the implementation of the green roof, but that the enterprise had this item for landscape purposes and environmental issues. It is observed in Table 03, that of the total area of green roofs presented in the architectural projects raised in this study, 93% fall within the mandatory law. However, of the remaining 7%, projects are not within the profile defined by law. This can be justified by the landscape appeal that brings greater added value to the product, the awareness of the customer that has become increasingly aware of environmental concerns, the reflection of public policies that are being gradually disseminated and adopted in Brazilian cities.

In contrast, of the 10 projects surveyed with housing, 3 units had removed the green roofs of their facilities. Once the maintenance is under the responsibility of the owner, they are susceptible to mischaracterization, making greater incentives and disclosure necessary for the implementation of the system by the Government (Table 03).

The mandatory installation of green roofs in the city of Recife started with Municipal Law n$^o$ 18,112/2015, object of this study, which was sanctioned on January 12, 2015. With the objective of contributing to the improvement of the environmental quality of buildings, makes it mandatory to install the green roof on multifamily housing buildings with more than four floors and non-housing with more than 400 m$^2$ of covered area and the construction of accumulation or delay reservoirs for the drainage of rainwater to the drainage network (RECIFE, 2015a).

This construction, destined to lots with an area greater than 500 m$^2$, built or not, and with a waterproofed area greater than 25% of the total area of the lot. These reservoirs may be built in natural soil, corresponding to up to 10% of this area. The accumulation reservoirs aim to accumulate rainwater for



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reuse for non-potable purposes, and the delayed ones, to accumulate rainwater for later discharge into the public network (RECIFE, 2015a).

Thus, for the approval of the architectural design of these buildings and the subsequent release of the building permit, it is necessary to provide for the implantation of a green roof on the uncovered pavement intended for vehicle parking, which can also be used as a floor slab for leisure. , and in the leisure areas, when located on a floor slab, in the percentage of 60% of its bare surface and at least 30%, in the leisure areas when on a covered slab. It also mentions that the Green Roof must have a minimum width of 2.00m (RECIFE, 2015b).

According to the law, the green roof may have extensive or intensive vegetation, being preferably native because it adapts better to the tropical climate of Recife, bringing balance to the environment where it is being inserted, improving the landscape aspect, reducing the heat island, retaining and reusing rainwater and positively interfering with the local microclimate.

Regarding the Political-Administrative Regions, in Table 04, it was possible to observe that most of the architectural projects deferred from January 2015 to September 2019 were for RPAs 3 and 4, presenting 26.5% and 23.8 %, respectively, which represents practically 50% of the total, as they have environs that are in increasing real estate speculation. However, RPA 4 (18,624.55 m²) and RPA 6 (18,415.77 m²) have similar green roof areas, especially RPA 1 (26,304.63 m²) for having architectural projects with large projects, mixed use, in São José environs.

Another factor to mention is the relationship of the presence of the enterprises about critical flooding areas. The malfunction of the drainage network causes serious problems to the road system in Recife during rainy periods, leaving flooded streets. The chaotic urbanization process added to the growing impermeability of natural soil aggravates the problem of urban drainage. With the overloading of the existing infrastructure, rainwater cannot run off superficially, accumulating water in the weakest points of the system, generating the critical points of flooding in the city. In addition, the city presents a spatial segregation, more valued environs are much more endowed with infrastructure and urban equipment, compared to the others (EMLURB, 2013). It is observed that RPA 5 is one of the regions with the highest number of critical flooding points, 22 units with only 02 approved projects. Another contrast is observed for RPA 3, which has 38 approved projects and only 09 flooding critical points (Table 04). In the Municipal Law, the object of this research, green roofs are presented as one of the measures that provides a solution for the management of rainwater, as well as the reservoir of delay or accumulation of rainwater, at the lot level. (SILVA JÚNIOR; SILVA, S., 2016).

*Table 3:* Deferred architecture projects with a green roof system, with and without obligation, post-municipal law No. 18,112 / 15, from January 2015 to September 2019, in the city of Recife. T-Student test for independent samples; ** p 0.01; * p 0.05.

| Deferred Processes | Green Roof area (m²) | Environs | Housing | Non-Housing | Mixed | Not started | Started | Occupation License | Kept after housing permit |
|---|---|---|---|---|---|---|---|---|---|
| Mandatory | 88.393,33** | 34** | 110** | 17* | 16** | 105** | 28** | 10** | 7 |
| Not required | 5.651,02 | 15 | 6 | 12 | 1 | 10 | 5 | 4 | no information |

*Table 4:* Architectural projects approved with green roof system by RPA and total area (m2) of green roofs planned between January 2015 and September 2019 in the city of Recife. Averages followed by the same letter, do not differ, by the Tukey Test, at the level of 5% probability

| RPA | Environs | Deferred Project | Green Roof Area (M²) | Total Projects By RPA | Total Green Roof Area Per RPA (M²) | Critical Flooding Points |
|---|---|---|---|---|---|---|
| RPA1 | BOA VISTA | 9 | 3.420,09 B | 27 | 26.304,63 | |
| | ILHA DO LEITE | 1 | 2.800,00 B | | | |
| | PAISSANDÚ | 1 | 1.158,41 B | | | |
| | RECIFE | 1 | 138,71 A | | | 22 |
| | SANTO AMARO | 7 | 6.802,59 B | | | |
| | SÃO JOSÉ | 6 | 11.529,63 C | | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| | SOLEDADE | 2 | 455,20 A | | | |
| RPA2 | ARRUDA | 1 | 628,39 A | 19 | 9.370,25 | 10 |
| | CAMPO GRANDE | 6 | 3.845,53 B | | | |
| | ENCRUZILHADA | 6 | 1.956,29 A A | | | |
| | HIPÓDROMO | 2 | 1.606,85 A | | | |
| | ROSARINHO | 4 | 1.333,19 A | | | |
| RPA3 | AFLITOS | 1 | 427,13 B | 38 | 13.769,09 | 9 |
| | CASA AMARELA | 11 | 3.459,72 E | | | |
| | CASA FORTE | 2 | 207,68 A | | | |
| | ESPINHEIRO | 6 | 1.829,12 C | | | |
| | GRAÇAS | 7 | 3.020,13 E | | | |
| | PARNAMIRIM | 3 | 1.215,24 C | | | |
| | POÇO DA PANELA | 1 | 555,20 B | | | |
| | SANTANA | 2 | 265,32 A | | | |
| | TAMARINEIRA | 5 | 2.789,55 D | | | |
| RPA4 | CAXANGÁ | 1 | 781,52 A | 34 | 18.624,55 | 14 |
| | CORDEIRO | 3 | 2.015,93 C | | | |
| | ILHA DO RETIRO | 4 | 2.300,36 C | | | |
| | IPUTINGA | 3 | 1.919,15 B | | | |
| | MADALENA | 8 | 4.011,35 | | | |
| | PRADO | 2 | 1.561,49 B | | | |
| | TORRE | 8 | 3.125,67 D | | | |
| | VÁRZEA | 5 | 2.909,08 C | | | |
| RPA5 | JARDIM SÃO PAULO | 1 | 1.053,36 B | 2 | 1.909,04 | 22 |
| | SAN MARTIN | 1 | 855,68 A | | | |
| RPA6 | BOA VIAGEM | 12 | 5.959,50 A | 23 | 18.415,77 | 30 |
| | IMBIRIBEIRA | 7 | 5.898,92 A | | | |
| | PINA | 4 | 6.557,35 A | | | |
| | TOTAL | 143 | 88.393,33 | 143 | 88.393,33 | 107 |

c) *Relationship between green roofs and the Political and Administrative Regions of the city of Recife*

In the Recife City Development Master Plan (PDCR), the urban space of Recife is divided into six Political-Administrative Regions, as shown in Figure 06, distributed in the central, north, northwest, west, southwest and south regions and formed by 94 environs. The RPA's were defined for the formulation, execution and permanent evaluation of government policies and planning (Lei Orgânica do Recife, Artigo 88, & 1º e 2º, 1990).



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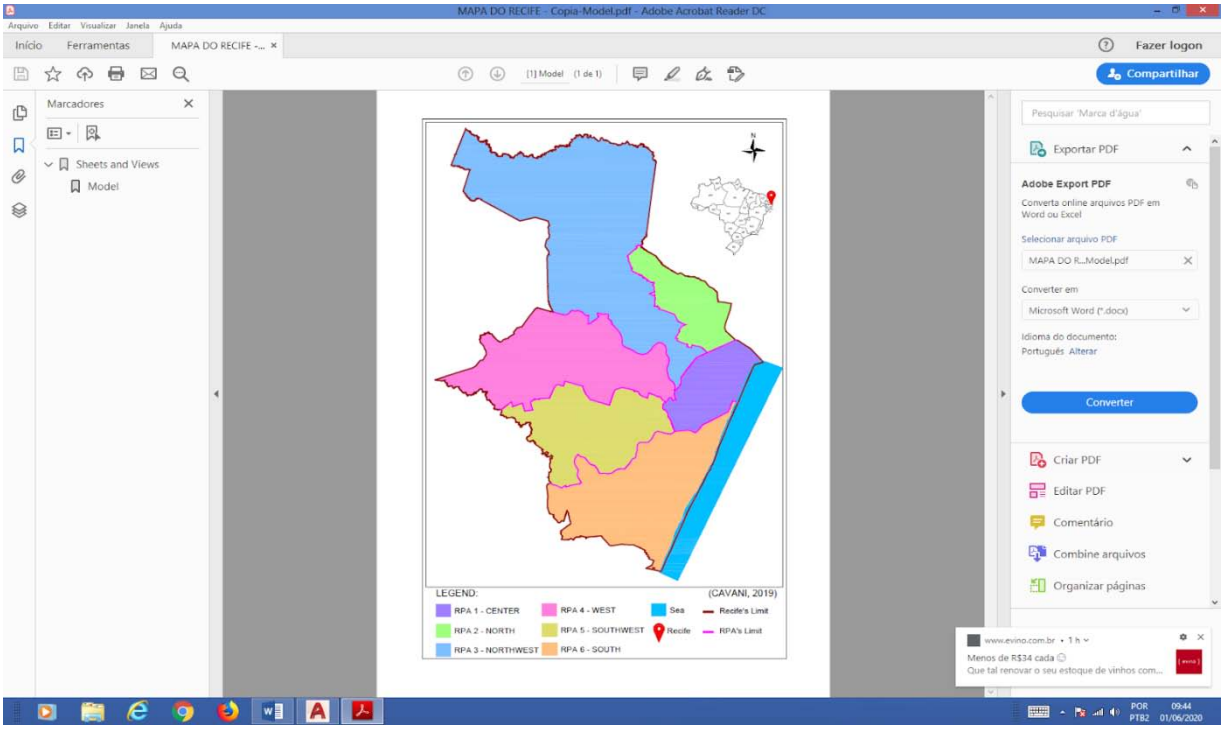


*Figure 6:* Political and Administrative Regions of Recife

In order to understand the spatial distribution of green roofs in the city's environs, a study was developed in the elaboration of cartograms, resulting in a set of seven maps, one of which is general of the city of Recife and another six, referring to each RPA.

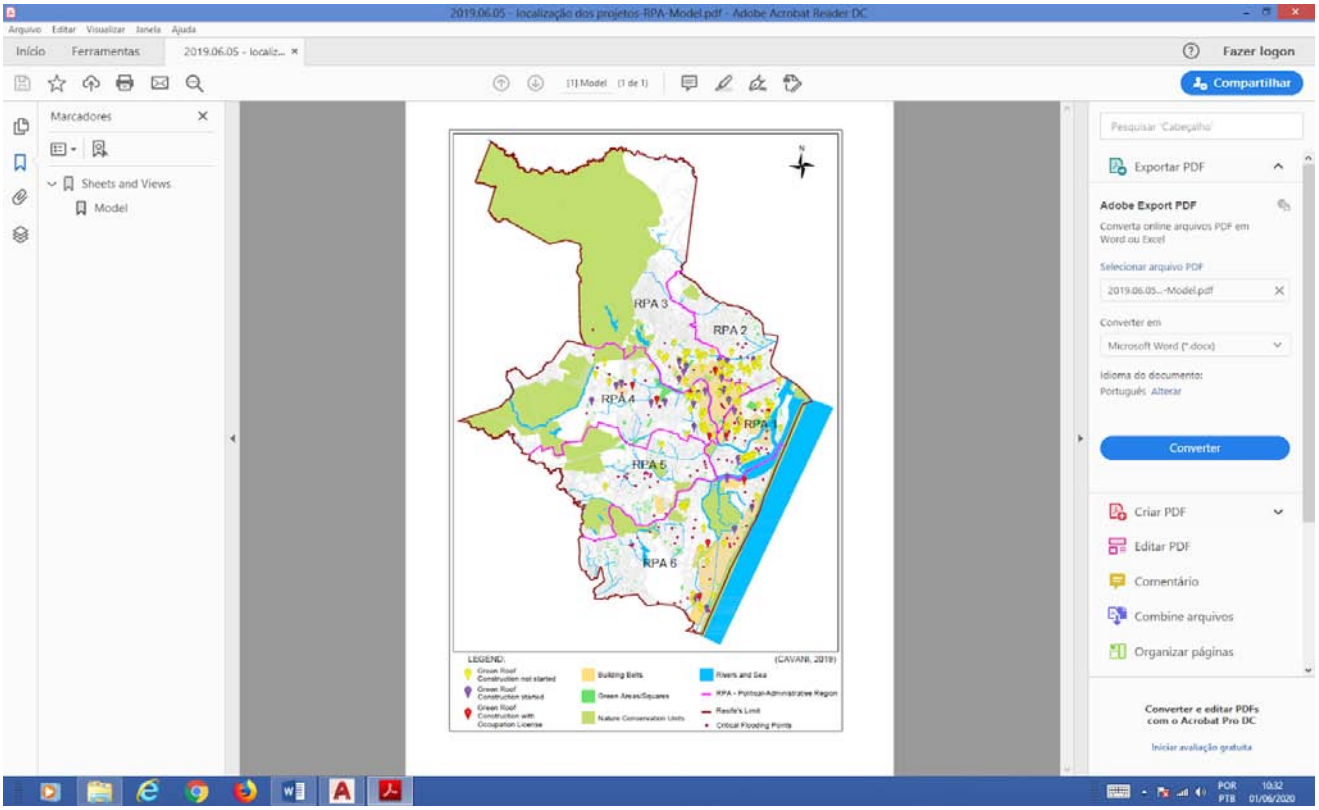


*Figure 7:* Distribution of green roofs in the city of Recife, located by Political-Administrative Regions



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The areas of green roofs, patches of building belts and critical points of flooding presented in Figure 07, although originated from several sources, were computed together, to demonstrate the relationship of these units with the locations of implantation of current and future green roofs.

This general map presents large masses of green areas, called Nature Conservation Units - UCN, which are part of the Categories of Protected Units, being of great importance for the mitigation of the climate. Protected Units are "the spaces and the natural and artificial elements of the municipal territory, under special attention and care due to some specific and / or unique attribute that they present. They have significant environmental and / or landscape interest, necessary to mitigate the climate and intended for the practice of activities: contemplative, cultural, recreational, sports, ecotourism, socializing or leisure, environmental education, scientific research" (MUNICIPAL LAW No. 18014/2014, ART. 6 OF CHAPTER III).

As for the building belts, an urban configuration characterized by the agglomeration of multi-storey buildings built without standardization, they present more predominant spots located, one in the south zone, close to the Atlantic Ocean, in RPA 6 and another, around the Capibaribe River, in the RPA's 1, 3 and 4. It is also possible to observe the disparity in the number of green roofs distributed in these regions, as a result of the evolution of urban occupation in the city and real estate appreciation in some environs.

The urbanization process in the city of Recife took place in a disorderly manner, resulting in an increase in impermeable areas and overloading the existing drainage system, resulting in a total of 107 critical points of flooding in the rainy periods and tidal fluctuations, as indicated in the general map. , the law being the object of this research, pointed out as one of the measures that provides a solution for the management of rainwater (EMLURB, 2018; SILVA JÚNIOR; SILVA, S., 2016; SILVA JÚNIOR et al., 2017).

According to Pinto (2014), there is the possibility of combining the installation of a green roof with the recent solutions for the use of rainwater, cisterns, or underground reservoirs, which may contribute to the complete elimination of runoff. These waters can be reused for non-potable purposes, for example, to feed irrigation systems, reducing water consumption, whether in public or private spaces.

The green roof can improve the quality of life in the city of Recife, which in addition to reducing the impacts of the heat island and the emission of greenhouse gases, has the property of absorbing and releasing part of the solar radiation, reducing the air temperature and raising the humidity of the air (BALDESSAR, 2012). It should be noted that, when applied to urban centers on a large scale, the Green Roofs interact with each other and with the environment in which they operate, constituting a stable, balanced and self-sufficient system, starting to play an important role in the maintenance of this healthy ecosystem (OSMUNDSON, 1999).

i. *RPA 1- Political-Administrative Region - Center*

In Figure 08, RPA 1 is composed of 11 environs, the environs of Recife, the stage of the beginning of the urbanization of the city of Recife, in the 16th century, due to its port location that facilitated the flow of commercial products at that time, Brazil and sugar cane. In the 17th century, with the arrival of the Dutch, there was a great urban intervention, with landfills and construction of bridges, starting the expansion of the island of Recife towards the current environs of Santo Antônio and São José, building palaces, churches, forts and markets. With the withdrawal of the Dutch the economic crisis and competition from the ports of Rio de Janeiro and Salvador put the region in decline, keeping only financial and export services, as well as commercial activities to serve dockers and sailors, gradually removing the population wealth, who starts looking for housing in more distant environs. The environs then undergoes a major emptying from the 1980s, when in 1991, the state government with several partnerships, transformed the environs into a tourist hub, revitalizing the area, being today an area linked to technology and of great importance historical and cultural (EMLURB, 2013; ZANIRATO, 2006).

All the environs belonging to this region are located in lowland areas, totaling 1,606ha, with emphasis on reduced afforestation due to the presence of *Parque 13 de Maio*, *Santo Amaro Cemetery*, *Praça da República*, mangrove area on *Joana Bezerra Island*, *Zeca Island*, taking advantage of the *Capibaribe River* estuary. The climate located in this central region is above 26°C, being warmer around 10°C, compared to the peripheral areas and the conservation units, located in the west of the city of Recife (BARROS; LOMBARDO, 2013; EMLURB, 2013).

The region also has a total of 22 critical flooding points, with the environs of São José and Santo Amaro having the highest number, respectively 10 and 03 occurrences of flooding (EMLURB, 2018). Of the 26,304.63 m² of green roofs planned to be installed in this region, the largest areas will be available exactly for these environs: 11,529.63 m² for São José and 6,802.59 m² for Santo Amaro, contributing to the improvement surface runoff of rainwater and ameliorating the region's hot climate. We also emphasize that the 03 buildings with works started corresponding to 2,424.00 m² of green roofs and those with housing, 3,056.88 m². It is noteworthy that in 1996 the Ilha Joana Bezerra environs had a built area of around 1,500 m², with the implementation of the Judge Rodolfo Aureliano Forum and the headquarters of the Association of Friends with Disabilities (AACD), has grown to 48,300 m² in seven

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years. Meanwhile, the Ilha do Leite environs showed an increase of 163% in growth due to the implementation of the Medical Center (EMLURB, 2013).

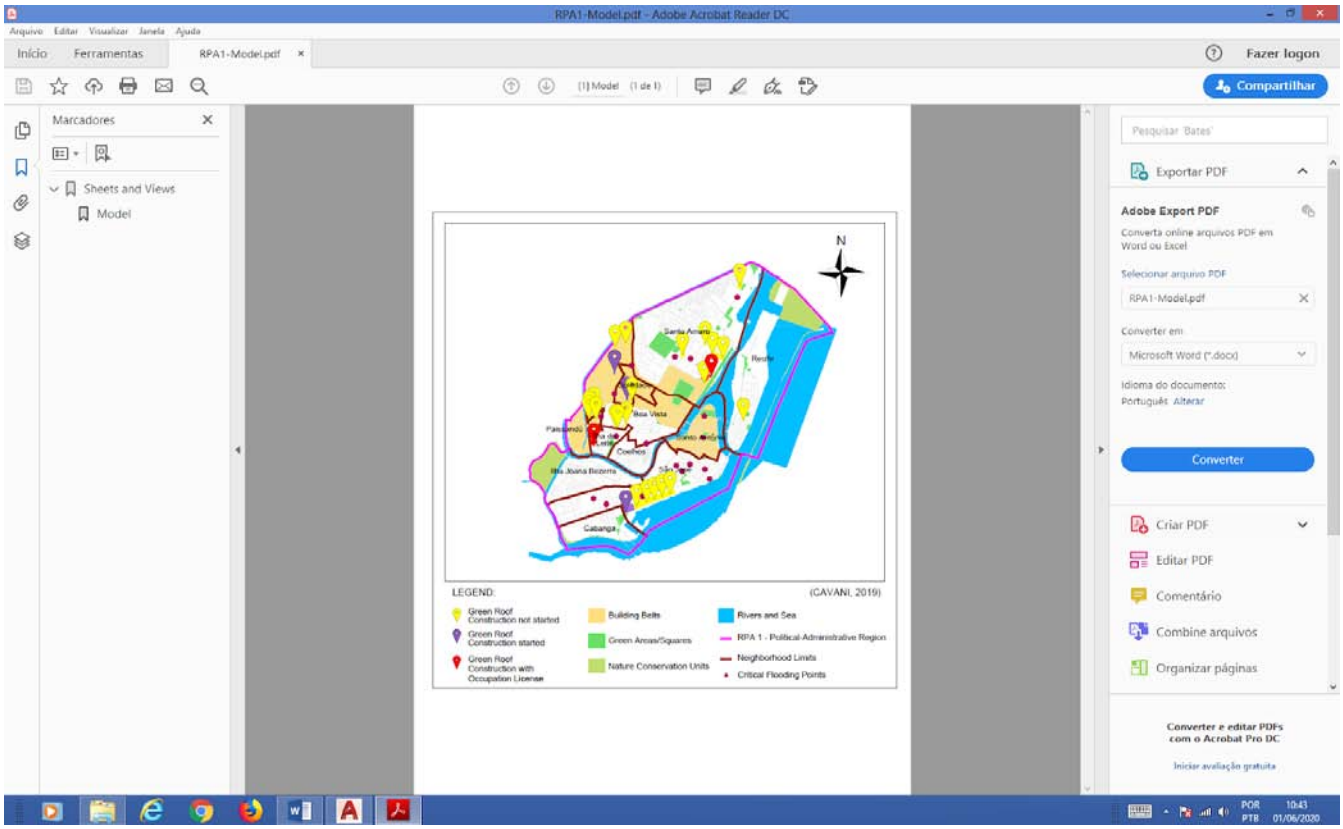


*Figure 8:* Political-Administrative Region RPA 1 with the location of the green roofs

ii. *RPA 2 - Political-Administrative Region - North*

As shown in Figure 09, RPA 2 is in the northern region of Recife, with 18 environs, the least extensive of the regions, with an area of 1,430 ha. The largest urban concentration begins on the banks of the Capibaribe River, towards the environs of Derby, Graças, Espinheiro and Aflitos, extending to Encruzilhada, Rosarinho and Campo Grande, due to the growing real estate speculation and for presenting a lowland area. RPA 2 has a smaller spatial distribution of green area, represented by the Dois Unidos Nature Conservation Unit, around 50 ha, in addition to squares and other refuges scattered throughout the region (EMLURB, 2013; OLIVEIRA *et al*., 2013).



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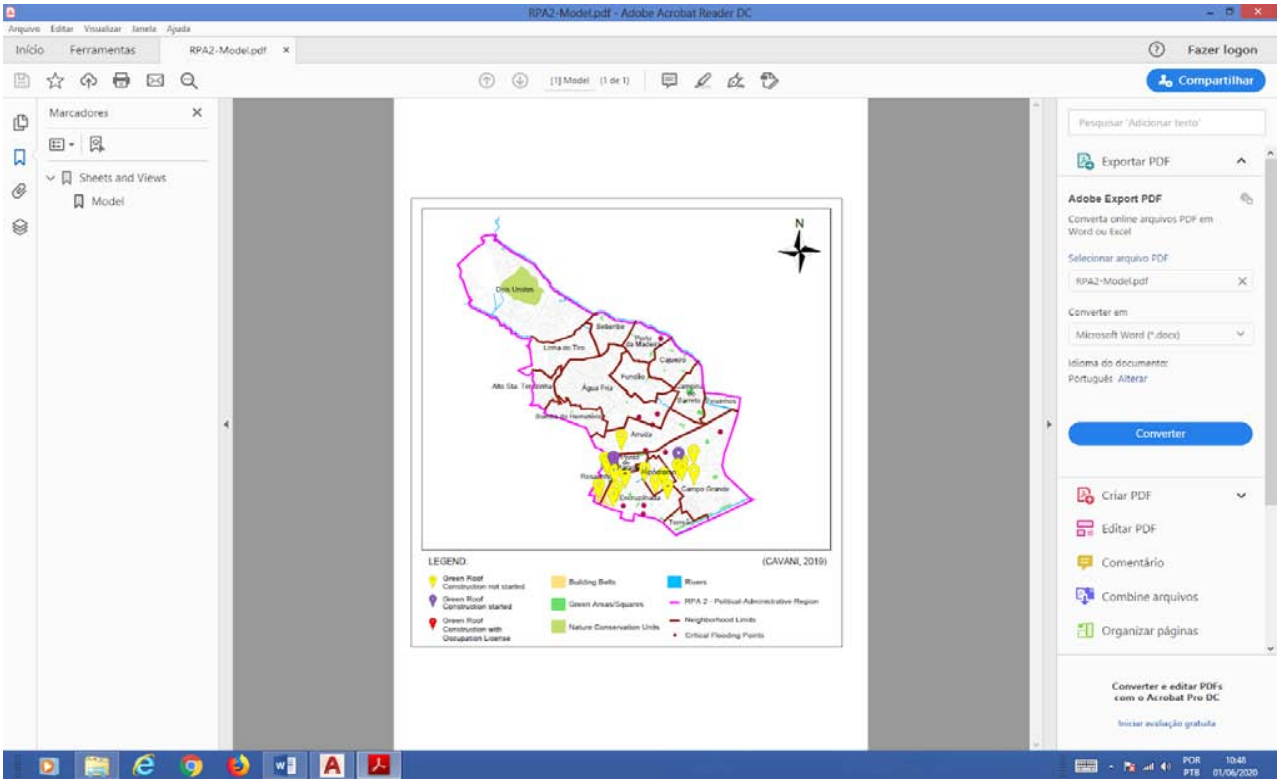


*Figure 9:* Political-Administrative Region RPA 2 with the location of the green roofs

The temperature of the region is above 26º, finding areas built on plains and coastal boards and hills, where there is an extensive heat island, partly due to chaotic urban occupation, with population density and sparse vegetation , in addition to the low quality of the materials used in the constructions allied to the growing waterproofing of the soil, with the paving of streets and stairs (BARROS; LOMBARDO, 2013).

RPA 2 presents a total of 10 critical flooding points, distributed among the environs of Água Fria, Arruda, Campo Grande and Encruzilhada (EMLURB, 2018). Of the total of 9,370.25 m² of green roofs planned to be installed in this region, it should be noted that most of them are included in the environs: Campo Grande, area of 3,815.53 m², in construction to start and 30.00 m² already started, Crossroads with 1,956.29 m² to start and in Rosarinho, an area of 857.12 m² to start and 476.07 m² of green roof area already started.

iii. *RPA 3 - Political-Administrative Region - Northwest*

Located in the northwest region of Recife, RPA 3, shown in Figure 10, has a greater number of environs in relation to the other regions, 29 units, being the most extensive of the regions, with an area of 7,781 ha, representing 35% of the area of the Recife. Historically, its urban evolution takes shape, from the 18th century, when urban growth begins to expand slowly and radially, starting from the center (RPA 1) towards the interior, due to the lack of interest of wealthy families in the use of the central region for residential purposes and the availability of new traffic routes that are being developed, such as railways and waterways. In this way, several mills installed on the plains gradually gave rise to lots and sites, forming the current environs of Derby and adjacent, up to Apipucos, following the top-hydrographic conditions, close to the Capibaribe River. It is also due to the strong reason for the urban occupation near the river, to the population's attractive to bathe in the river, not having in the middle of the 18th century, habit for bathing in the sea. The replacement of old horizontal houses with buildings for multifamily residential use and real estate investments were gradually starting in 2003, allowing for a building density in the environs of Derby, Espinheiro, Graças, Aflitos and part of Parnamirim and Tamarineira (EMLURB, 2013).

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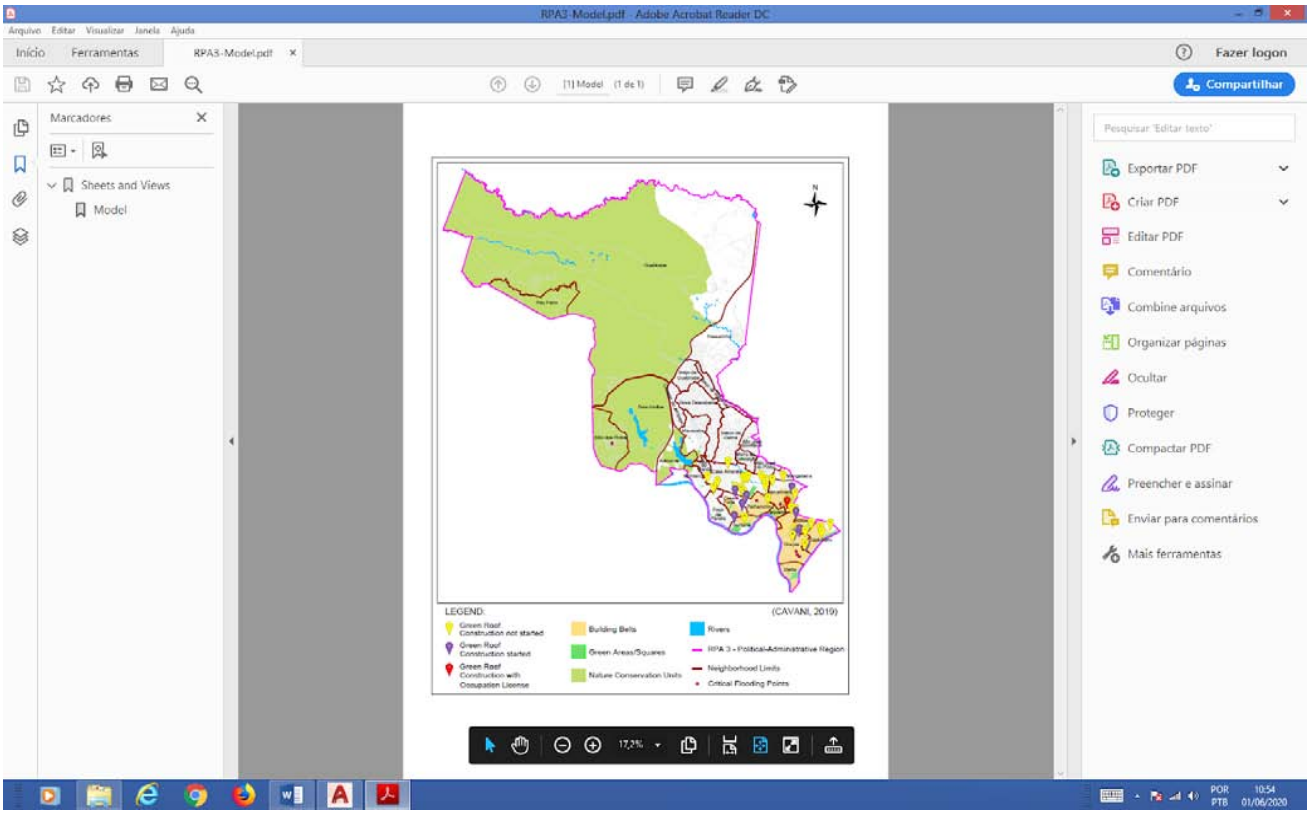


*Figure 10:* Political-Administrative Region RPA 3 with the location of the green roofs

This region has a vast green patch, representing 49% of the total green area of the city of Recife, represented by the Beberibe Nature Conservation Units, Dois Irmãos, Sítio dos Pintos, Capivaras Park and the Apipucos Weir, in addition to the Parks da Jaqueira and Tamarineira (EMLURB, 2013; OLIVEIRA et al., 2013). The temperature in this region varies from 22º to 26º and may be aggravated by heat waves due to the existing construction network and the growing real estate speculation. (BARROS; LOMBARDO, 2013).

The region has a total of 9 critical flooding points, with 3 concentrated in the environs of Graças (EMLURB, 2018). Of the 38 architectural projects deferred in this region with a total area of around 13,769.09 m² of green coverage, 01 buildings are located at 251.44 m² and 09 are under construction, with a total of 3,111, 51 m² of green roofs, contributing its benefits to make the city more sustainable.

iv. *RPA 4 - Political-Administrative Region - West*

The RPA 4 region, located west of Recife, shown in Figure 11, has 12 environs, the second most extensive in the city of Recife, with 4,214 hectares. Its urban development follows the same guidelines reported in RPA 3, where the installed mills gradually gave rise to lots and sites, initially developing the current districts of Madalena and Torre, also following the topographic conditions, close to the banks of the Capibaribe River, where we can see a greater urban concentration, which will expand towards the Ilha do Retiro environs (PREFEITURA DO RECIFE, EMLURB, 2013).

This area has the second largest spatial configuration of green area, with 46.90% occupied by vegetation, most of which comes from the remaining forests of the old engenhos of Várzea (OLIVEIRA et al., 2013). The temperature fluctuates between 24º and 26º, where the building network located in the environs of Madalena and Torre, are still not very affected by heat pockets because they are close to the Capibaribe River with its mangrove vegetation, contributing to keep the temperature of the your surroundings (BARROS; LOMBARDO, 2013).

The region has a total of 14 critical points with flooding problems, with a greater concentration between the environs of Caxangá, Iputinga and Várzea (EMLURB, 2018). It houses 34 deferred architecture projects, with a total area of 18,624.55 m² of green coverage, where 09 buildings are under construction and 04 with habitation, presenting respectively total areas of 4,338.37 m² and 1,431.89 m² of green roofs, with the districts of Madalena and Torre more representative, due to the real estate speculation that is expanding in that area of the city.



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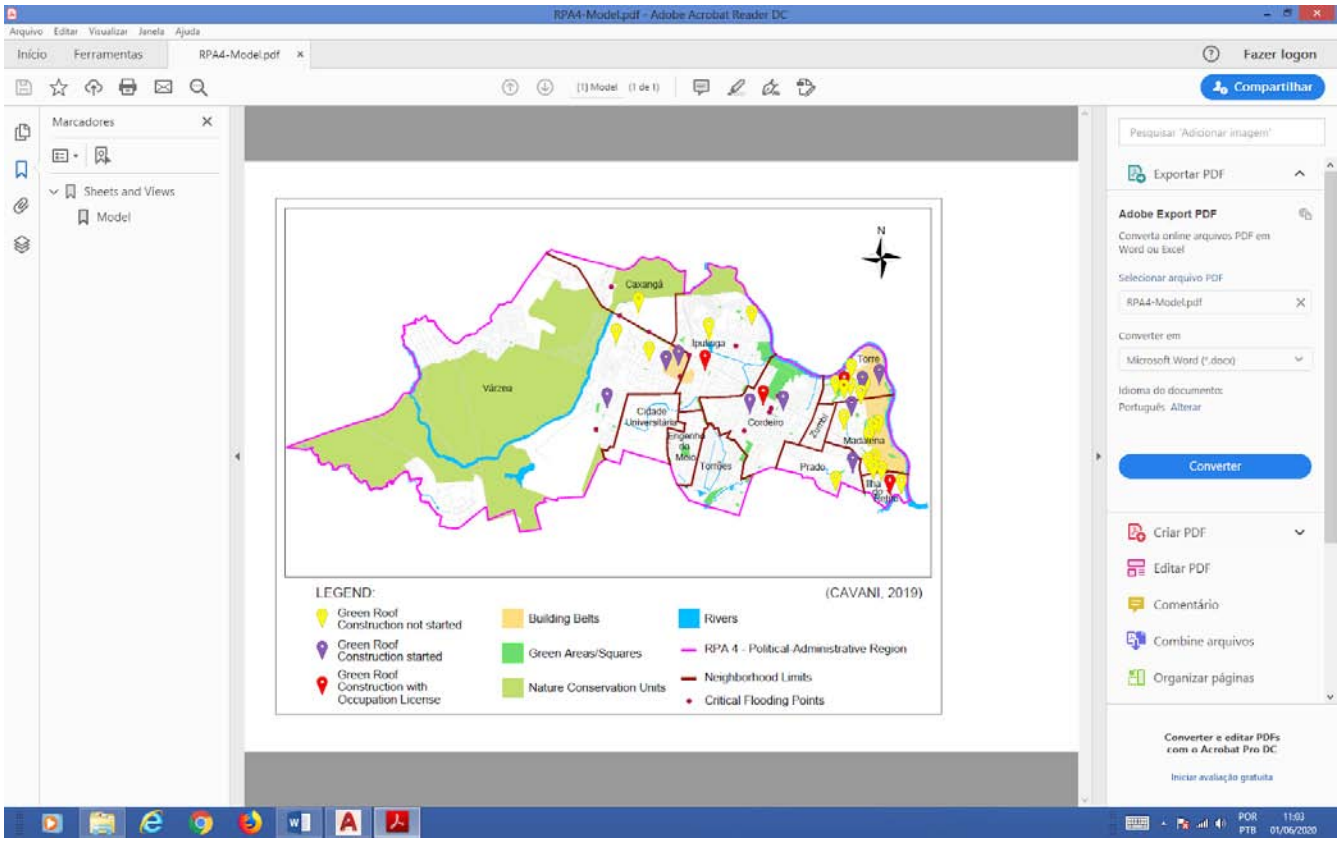


*Figure 11:* Political-Administrative Region RPA 4 with the location of the green roofs

v. *RPA 5 - Political-Administrative Region - Southwest*

In the beginning of the 20th century, after the first urban and sanitation reform in the city of Recife, there was a population growth of around 46%, where this expansion started to be directed to the Afogados environs, initially extending to Estância and Areias, along the axes of existing urban routes, Av. José Rufino and Rua São Miguel. The urban fabric of Recife is characterized by the uneven layout of its spaces, where the flatter areas are more valued in the real estate market and better served by urban infrastructure, while elevated areas, in some environs such as Barro, Tejipió, Curado, Totó, Coqueiral , present problems of high risk of landslides, due to geological conditions and inadequate urban occupation, generating soil with erosion and little vegetation (BARROS; LOMBARDO, 2013; EMLURB, 2013). Due to the devaluation and lack of real estate interest in the region, there are only two construction projects not started with green roofs in the environs of San Martin and Jardim São Paulo.

Located in the Southwest region of Recife, RPA 5 consists of 16 environs, in an area of 3,025 ha, with its main green patches represented by the Curado forests, Mata do Barro, Jardim Botânico and Campo do Jiquiá. There are also 22 critical flooding points, predominantly in the Estância and Afogados environs (EMLURB, 2018).

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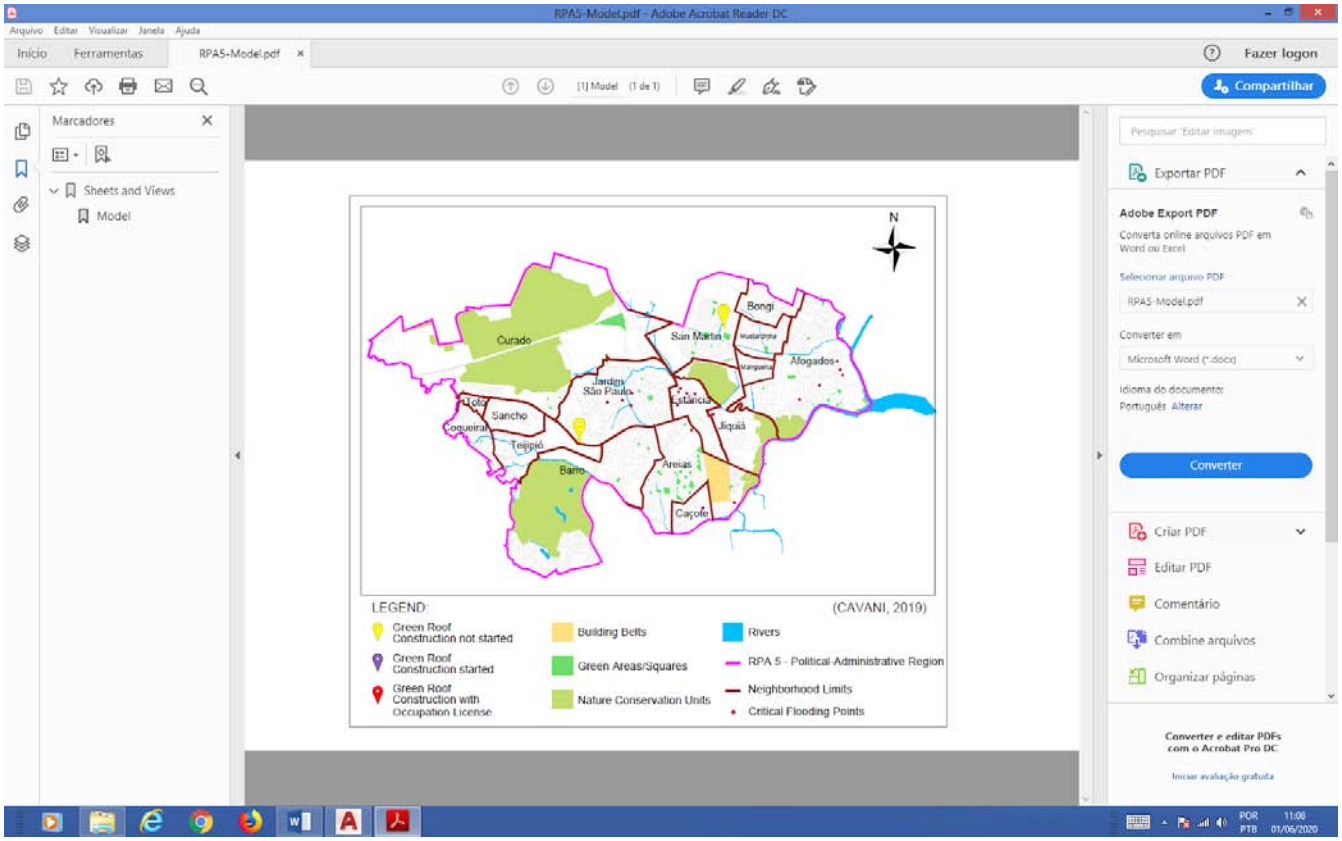


*Figure 12:* Political-Administrative Region RPA 5 with the location of the green roofs

vi. *RPA 6 - Political and Administrative Region - South*

As shown in Figure 13, RPA 6 is located in the southern area of the city of Recife, formed by only eight environs, with an 8 km long beach, located in the environs of Boa Viagem and Pina. In the middle of the 20th century, Boa Viagem was occupied by a fishing community, a small church and military bases of the Navy and Air Force, because of the Second World War. After a few years, it became a summer place, where some residences started to be built, giving way later to small urban agglomerations. The desire to live on the coast, the demographic increase, combined with the improvement of the environs's infrastructure, with new road accesses and bridge construction, allowed a greater connection with the center of Recife, contributing to the appreciation of the environs and increasing real estate speculation. (COSTA *et al*., 2008).

A major change in the urban landscape began to emerge, where houses were replaced by tall residential and commercial buildings, and by hotel expansion. From the set of existing coastal ecosystems, such as vegetated dunes, mangrove forests, they were gradually transformed into a building belt, leaving two large Protected Nature Units, the Maritime Border and the Mangrove Park, in the Pina environs, great ecological and landscape importance for the city, besides contributing to soften the environs climate (COSTA *et al*., 2008).

The intense verticalization of buildings presented in the region has serious environmental consequences for the surroundings, preventing the action of the wind coming from the sea and creating islands of heat. The professor at the Federal University of Pernambuco, meteorologist Ranyere Nóbrega, conducts research in relation to the heat islands and stresses that some regions of Recife in this summer of 2019 may have a thermal sensation of 39 ° C, places that have replaced the natural environment with asphalt and buildings. Points out the Ipsep and Imbiribeira environs, as one of the hottest areas in Recife (JORNAL DO COMÉRCIO, 2019).

RPA 6 is spread over an area of 3,902 ha, being the most populous in the city of Recife, pointing to a total of 30 critical flooding points, 10 of which are concentrated in the Boa Viagem environs (EMLURB, 2018). Of the 18,415.77 m² of green roof areas foreseen in the 23 architectural projects approved in this region, result in 1,529.40 m² in buildings with housing, in addition to 909.39 m² of green roofs in works already started in the environs of Boa Travel and 5,367.63 m² in the Pina. Still expected to build 5,545.69 m², 4,397.28 m² and 666.38 m² of green roofs in the environs of Imbiribeira, Boa Viagem and Pina, respectively, contributing with their benefits for the reduction of urban heat islands and greenhouse gases. (SCHMIDT, 2009; BALDESSAR, 2012; CATUZZO, 2013; PEREIRA, 2017).



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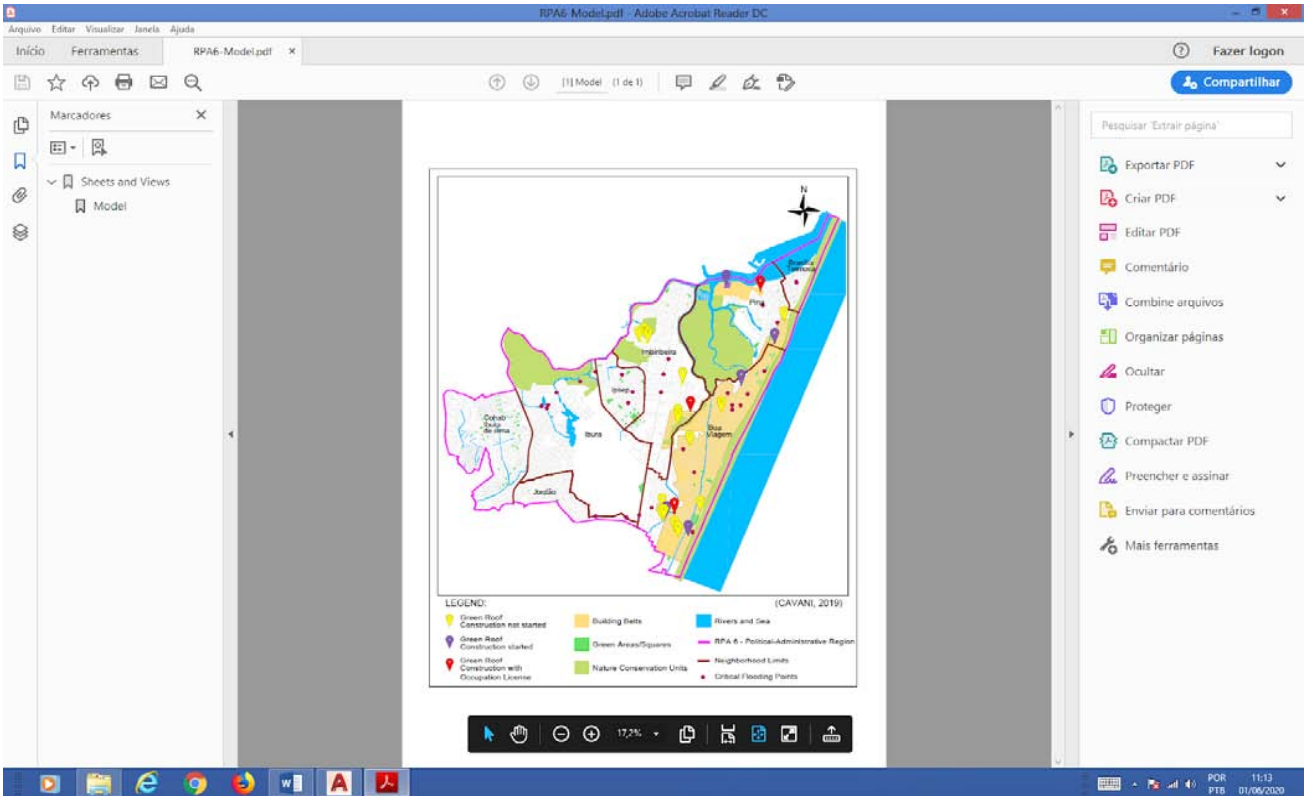


*Figure 13:* Political-Administrative Region RPA 6 with the location of green roofs

In general, it is observed that in the documentary research, 143 architectural projects approved by the City of Recife with the green roof system were quantified, between January 13, 2015 to September 30, 2019, representing a total area of 88,393, 33 m² of green roofs. However, of this total, in a field survey in the month of September 2019, it was found that the areas of green roofs in buildings with habitation added to those of buildings in the construction process correspond to an area of 22,926.58 m². Of this area, approximately 23.90%, 2.21%, 14.67%, 25.17% and 34.05% are located in RPA 1, RPA 2, RPA 3, RPA 4 and RPA 6 respectively. of the territorial outline established by these Political-Administrative Regions, the data also demonstrate that the green roofs had greater representativeness, when analyzed under the quantitative aspect, in the constructions of the multifamily housing type.

If the other developments are built, the green roof areas to be made available will be 20,823.75 m² (RPA 1), 8,864.18 m² (RPA 2), 10,406.14 m² (RPA 3), 12,854.29 m² (RPA 4), 1,909.04 m² (RPA 5) and 10,609.35 m² (RPA 6). It should also be noted that, of the total area of green roofs (65,466.75 m²) of works not started, around 45% correspond to projects approved in 2019, as a result of the heating of the real estate market, whose construction did not have time to appear in the research as works initiated.

From the data obtained from the quantity of green roofs and their locations in the urban network, it can be seen that most of them are inserted in the agglomerations of vertical buildings, in areas of intermediate temperatures from 24° to 26° C, with a predominance of higher values , in environs with few green areas available in their courts and in places with critical flooding problems, such as São José, Encruzilhada, Graças, Cordeiro and Boa Viagem.

What could be observed after the research carried out on the subject, the field survey, the statistical analysis of the data and, more than that, with the architectural and urbanistic feeling that permeated the entire development of this work, is that, being Recife a city lacking green spaces, with a disorderly urbanization process, unbearable automotive congestion, atmospheric pollution, intense heat, drainage hampered by the lack of basic sanitation infrastructure, the green roof system with its numerous benefits is presented, as one of the attitudes of hopes seeking to improve the environmental quality of the city.

In this context, Municipal Law 18,112 / 2015 proves to be necessary as an instrument to guarantee the applicability of green roofs in the city of Recife, where the Public Power must always create, disseminate and encourage public policies that induce protection to the environment. This Law provides for the obligation, but does not provide incentive mechanisms for the construction and preservation of the green roof

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system, through discounts or exemptions in the IPTU, like other cities in Brazil and abroad that have granted tax incentives. And this is justified because, although the burden of implementing the green roof is on the building owners, the benefits are diffuse, it is shared by the whole community, with the improvement made in the quality of life of the city.

As usually happens with every new law, needing time for understandings and adaptations, it was no different with Municipal Law nº 18,112 / 2015, referring to the green roof. It is believed to have gone through a difficult start of application, due to the lack of clear understanding about the conditions and limits of the Law, in view of the need for clarification procedures (SERVICE INSTRUCTION N.001, 2015; RESOLUTION N.01, 2019; MUNICIPALITY OF RECIFE).

This fact was clearly observed in the analysis of the architectural projects surveyed between the years 2015 to 2017 (55 projects), compared to the years 2018 to 2019 (88 projects), where there was a significant growth in their quantity. In addition, the search for sustainable solutions in projects, combined with the best knowledge and applicability of the Law, remains patented in the fact that the projects have adopted green roofs, in addition to the mandatory locations, in those that were not required by law, such as marquees, walkway slabs interconnecting building blocks.

## V. Final Considerations

The realization of this research allowed us to see, with the results obtained, that the green roof system is still little used in the city of Recife, indicating the need for the Government to adopt incentive measures, through tax deductions or subsidies, such as the use of IPTU.

However, it is not enough to enforce the Law, it is not enough to demand the approval of projects, it is not enough to put it into practice to allow the inhabitants to live in the building, it is necessary that a system of inspection be implemented by the Government to monitor green roofs, so that they remain as approved, under the penalty of seeing the Law become a greenwashing, counting the green roofs as existing after the inhabit and have actually been deactivated, being a great loss to the city's environment. Greenwashing is understood as "unjustified appropriation of environmental virtues by companies, governments, people, through the use of marketing techniques or public relations, hiding or diverting attention from negative environmental impacts generated by it" (https://pt.wikepedia.org).

That there is greater dissemination of the technique of the green roof system, making the population aware of the need to implant and preserve green to improve the quality of urban life. That future research be carried out, seeking to identify the vegetations that best adapt to the climate characteristics of the city of Recife. Thus, that green roofs can effectively perform their environmental and urban applicability. It is also important to highlight the innovative use of green roofs as a source of food and income generation, so that they can benefit the population with job offers and promote more sustainable food.

It should be noted that the financial crisis that hit Brazil, and the Brazilian real estate sector, brought significant reflections on the volume of data, completed buildings, available for the study. However, this reduction was not able to overshadow the importance of the Law in terms of its relevance for the transformation of the city into a more human and pleasant environment. And it is this importance that must be considered with the ongoing economic recovery so that one can have a better quality of life in the city of Recife.

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