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Green roof: a bibliometric analysis and its importance to the environment

The present work presents a study of bibliometric analysis on green roofs and their viability for the Judiciary of Pernambuco. Thereby, the green roof is characterized as a technique that allows the planting of plants on the roofs of buildings and residences in order to promote quality of life, energy savings and reduction of heat islands. It proposes to show how the practices of green roofs are conceptualized and how are the numerous benefits they provide, such as: reduction in electricity consumption; reduction of the internal heat of the building; improvement in the building's acoustic insulation; reduction of rainwater runoff; reduction of heat island impacts and greenhouse gas emissions; improvement in air quality and aesthetic effects, with greater visual comfort for its users, change in the image of the judiciary as a more modern institution concerned with the issue of sustainability and the need to preserve the environment. After Resolution 201/2015, sustainable buildings, in particular, green roof techniques have contributed to the promotion of sustainability in judiciary bodies. The present work aims to carry out a bibliometric analysis on green roofs and their feasibility for implementation in the Judiciary of Pernambuco and performs a literature review of a focal approach, with reading of published material, books, articles and others. For that matter, based on the survey and analysis of scientific articles, the results showed a growth trend in the number of articles published, which reveals a concern to deepen the reflection on this theme. The methodology used is that, given the importance of implementing green roofs, this work intends to make a bibliometric analysis, because with the impact of publications on green roofs, there is an increase in scientific production on this subject.

Keywords: Judiciary Branch; Sustainability; Green Roofs.

Telhado verde: uma análise bibliométrica e sua importância para o meio ambiente

O presente trabalho apresenta um estudo de análise bibliométrica sobre telhados verdes e sua viabilidade para o Poder Judiciário de Pernambuco. Assim, o telhado verde caracteriza-se como uma técnica que permite o plantio de plantas nas coberturas de edifícios e residências com o objetivo de promover qualidade de vida, economia de energia e redução de ilhas de calor. Propõe-se a mostrar como são conceituadas as práticas de telhados verdes e como os inúmeros benefícios que proporcionam, tais como: redução no consumo de energia elétrica; redução do calor interno do edifício; melhoria do isolamento acústico do edifício; redução do escoamento de águas pluviais; redução dos impactos das ilhas de calor e emissões de gases de efeito estufa; melhoria da qualidade do ar e dos efeitos estéticos, com maior conforto visual para seus usuários, mudança na imagem do judiciário como instituição mais moderna preocupada com a questão da sustentabilidade e com a necessidade de preservação do meio ambiente. Após a Resolução 201/2015, as construções sustentáveis, em especial, as técnicas de telhado verde têm contribuído para a promoção da sustentabilidade nos órgãos judiciários. O presente trabalho tem como objetivo realizar uma análise bibliométrica sobre telhados verdes e sua viabilidade para implantação no Poder Judiciário de Pernambuco e realiza uma revisão bibliográfica de abordagem focal, com leitura de material publicado, livros, artigos e outros. Nesse sentido, com base no levantamento e análise de artigos científicos, os resultados evidenciaram uma tendência de crescimento no número de artigos publicados, o que revela uma preocupação em aprofundar a reflexão sobre este tema. A metodologia utilizada é que, dada a importância da implantação de telhados verdes, este trabalho pretende fazer uma análise bibliométrica, pois com o impacto das publicações sobre telhados verdes, há um aumento na produção científica sobre este assunto.

Palavras-chave: Poder Judiciário; Sustentabilidade; Telhados verdes.

Topic: **Desenvolvimento, Sustentabilidade e Meio Ambiente**

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INTRODUCTION

The world has been experiencing a variety of environmental factors for a long time, such as economic development, energy transformations, urbanization, climate aspects and global warming. Mankind has been transforming nature, diverting water courses, building roads, excavating mountains, harming various species of animals and plants, affecting their health and well-being, since the quality of human life is directly linked to the quality of the environment.

In urban spaces, environmental degradation is caused by population growth, resulting in built-up and waterproofed areas without any concern for environmental impact. And with increasing urbanization, environmental problems become increasingly frequent, such as an increase in the flow of rainwater on roads due to the waterproofing of the land, the emergence of heat islands, generating more expenses with energy consumption and air conditioning, etc. (GULDE et al., 2022).

Thus, in a period in which sustainable actions are discussed, the green roof appears as a recent solution to sustainability issues in large metropolises, due to the high concentration of heat islands and other environmental problems (BENETI, 2016).

The use of the covered area of buildings for the implantation of vegetation with the technique of green roofs is presented as an alternative to compensate for the suppression of vegetation in the urbanization process, whose scientific studies on this emerging theme show that this technique has been frequently discussed, finding worldwide evidence and used in several countries (BERARDI, et al., 2014; LUZ, 2017; RANGEL et al., 2015; SETTA, 2017).

Transporting its green rays, reaching the national territory, in a more intense way, Dutra (2019) adds that the perspective of disseminating the use of the green roof in Brazil is proven with positive experiences in many Brazilian cities, in residential buildings and in publics agencies that have taken initiatives to encourage sustainability.

Within this perspective, green roofs in buildings have been shown to be one of the efficient alternatives in reducing energy consumption for cooling indoor environments, in hot climates, but also in several aspects related to environmental sustainability (MELO et al., 2017).

The socio-environmental initiatives within the Brazilian Judiciary only took place after the creation of the CNJ (JARDIM, 2016). By publishing Resolution No. 201/2015, the CNJ makes available to the courts a consolidated tool, with clear prescriptions that can be complied with, and seeks to remedy, through the institution of the Sustainable Logistics Plan (PLS), existing gaps in the structure of organizations that need socio-environmental measures (MELO et al., 2021).

It is therefore noted that, with the great importance of the green roof, the present work intends to analyze bibliometrics, because with the increase of publications on green roofs, an impact on productions, journals and scientific authors can be seen to have greater monitoring and development of this renewable energy.

THEORETICAL REVIEW

Green roofs

In the face of a period in which sustainability actions are discussed, the green roof appears as one of the solutions to sustainability issues in large metropolises, due to the large concentration of heat islands and other environmental problems (BENETI, 2016).

Green roofs, also known as vegetative or eco-roofs, are horizontal structures with vegetation cover placed on top of buildings, on roofs (SILVA et al., 2018).

A new model of sustainability is needed, including greater incentives to save energy, reduce consumption and protect the environment, while at the same time increasing citizens' levels of well-being. In addition to the sustainability of the construction of the future, it should also consider the “visuality” and “functionality” of buildings (RIFFAT et al., 2016).

Due to this new look at sustainability, engineers and architects are looking for new construction techniques, in which there is a unification between the aspects of civil construction and the aspects of the environment, in order to have benefits aimed at minimizing expenses and taking advantage of the resources that nature offers, creating new sustainable constructions (COLARES, 2019).

> Thus, the use of green roofs can be seen as one of the main techniques to mitigate the problem situation, as it increases the amount of green areas favoring ecological aspects and, mainly, the use of rainwater. This is because in this type of cover, much of the precipitated water infiltrates and can be captured, which makes its use possible. (TONIAL, 2017)

Phoomirat et al*.* (2020), inspired by nature, states that green roofs are movements that seek to reduce the impacts of urban life, improving the urban environment and the quality of human life. In order for the coexistence between man and the environment to be a symmetrical relationship, it is essential that there is an improvement of the small urban spaces available, in which priority is given to the preservation of the environment with green technologies, replacing the dark concrete surfaces with a better environmental quality.

In addition to a natural look, ecological roofs provide environmental services of filtering air pollution, reducing the effects of heat islands, increasing air humidity, soundproofing and generating energy savings. Therefore, it is a sustainable alternative that generates well-being to human beings, improving their living conditions in big cities. In urban areas, which are highly impermeable, the use of green roofs reduces and delays surface runoff from rainfall, as it increases the permeable surface, preventing and adverting the formation of floods (FRIZON et al., 2018).

In Europe, this technique has been used as a way of reducing the concentration of carbon in the air, in addition to the relevant benefits such as reducing energy demand for air conditioning in the summer, especially in warmer regions. This factor has made its use more popular because, in addition to enhancing the environment aesthetically, it also helps with energy and environmental issues (FERRANTE et al., 2016).

In countries like Norway, the main contribution of green roofs is absorption of CO2, local climate regulation, in addition to stormwater management, reducing runoff after precipitation events and melting snow (BRASKERUD, 2014).

Thus, the use of green roofs will not only favor the place of installation, but the places close to it, since with the humidity of the vegetation it will imply a significant climate and air improvement in the surroundings of the building contemplated with the green roof. Green roofs are increasingly popular in urban areas as they offer a number of benefits, including retaining rainwater, cooling buildings and promoting biodiversity (HENK et al., 2020).

In this sense, several companies that have developed projects on various types of green roofs have emerged in recent years, and the perspective is that over the years there will be a growth of companies in this sector. Economically, it is believed that due to the increase in compensation policies for the adoption of sustainable techniques in enterprise and with the emergence of new companies, the competitiveness that will arise will make prices better adjusted, making the technology attractive to different economic classes. (DUTRA et al., 2019). As an example, in Figure 1, a green roof on the roof of a building in the city of São Paulo.

Figure 1: Green Roof . **Source:** Trees of São Paulo (2019).

Figure 2: Charles Darwin Business, Recife. **Source:** Sustentarqui (2014).

In Recife, initiatives of hanging gardens in the capital's buildings help to reduce heat islands and point to improvements for the city. They are still few. Counted on the fingers. But they already make a difference in the landscape of the capital of Pernambuco. Pioneers, they arrived even before the approval of a bill that makes it mandatory to install green roofs on the roof of buildings, shown in Figure 2.

Green roof components

The green roof seen in Figure 3 is made up of several layers, each of which has a specific function. Casagrande (2008) compared the layers of the green roof to the thin layers of a sandwich, in which the upper layer will be composed of vegetation and the lower layer would be the roof platform.

Usually, the basic structure is composed of six layers, represented in Figure 3, having their specific functions (KOZMHINSKY et al., 2016; LUZ, 2016): Waterproofing layer: prevents water infiltration into the slab, by applying bitumen or synthetic blanket; Protection layer (anti-root): prevents the action of aggressive roots from damaging the waterproofing layer; Drainage layer: it is responsible for regulating the water retention, necessary for the vegetation during periods of drought, composed of expanded clay, gravel or rolled pebble or even other models made of plastic such as trays or hollow boxes, allowing the circulation of water; Filtering layer: it has the function of preventing the passage of substrates, benefiting the circulation of air and water in the drainage layer, using bidin (filtering fabric) or geotextile blanket; Substrate layer: where the nutrients that support the vegetation are found, helping in the capture and temporary storage of rainwater; Vegetation layer: it is the vegetation cover itself, and must be adequate to the climatic conditions of the region where it is inserted, and can be designated as extensive, semi-intensive and intensive.

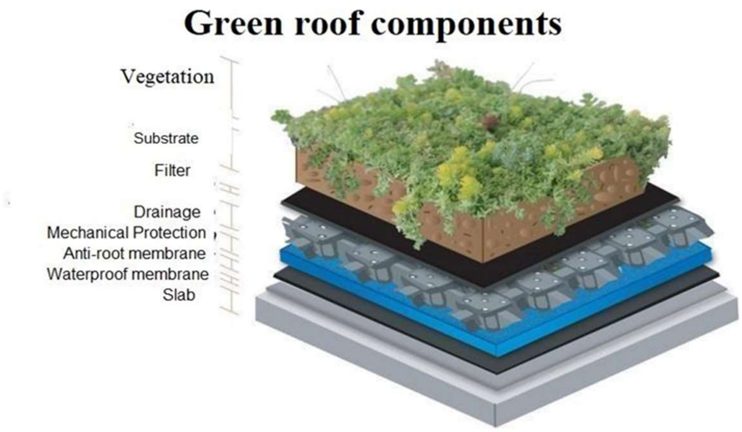

Figure 3: Green roof components. **Source:** Jesus (2018).

Benefits of using green roofs

Green roofs are sustainable practices that can provide several ecological and environmental benefits, such as rainwater management, reduction of building temperature for ambient cooling, reduction of energy consumption, improvement in the functioning of the urban drainage system, preservation of plant diversity, as well as habitat for birds and increase in urban gardening enhancing the aesthetic look (PHOOMIRAT et al., 2020). According to Rola (2008), the benefits of green coverage can be classified through three aspects, at the owner, population and urban ecosystem scale, as shown in Table 1.

Table 1: Benefits of green roofs.

To the owner	To the community	To the environment
Extends coverage life	Reduces the surface flow of rainwater	Prevents backflow of drainage
Reduce air conditioning consumption during the summer	Reduces the effect of heat islands in cities	Reduces the impact of carbon dioxide
Reduces heating consumption during winter	Reduces thermal inversion	Removes nitrogen contained in rainwater
Stormwater management tool	Reduces the noise	Counteracts the effect of acid rain
Likely to receive tax incentives	Reduces energy demand	
Promotes public relations	Improves air quality	Favors the consolidation of urban biodiversity with birds and insects.
Use of unused area as garden space	Improves aesthetics	

Source: Rola (2008).

Materials used in civil construction stocks solar radiation and re-emits this radiation in the form of heat, making cities up to 17º C higher. The accumulation of this heat during the day, due to the absorption properties of the materials used in the construction, compromises its durability and wear, consequently reducing the useful life of the building (MENDES et al., 2017).

Thus, investigating the thermal efficiency of the green roof in relation to traditional roofs, Vecchia (2005) developed a study reporting the external temperature and the thermal variation inside the environment, performing an equation between the thermal behavior of the green roof with traditional systems of existing coverage in Brazil. Through the results presented in Table 2, it was observed that the internal thermal amplitude of a building with a green roof is on average 9.2°C, while the external one is 21.4°C. Lopes (2007) proved that the green roof reached levels of thermal amplitude 50% lower than the oscillations of the exterior. This characteristic means that the environment in which the green roof was implemented does not have a very large temperature variance throughout the day in comparison to the outside temperature, making the environment thermally more pleasant.

Table 2: Variation in thermal amplitude.

	S.I (°C) Ceramic Tile	S.I (°C) Galvanized Steel	S.I (°C) Fiber Cement 6mm	S.I (°C) Concrete Slab	S.I (°C) Light Green Roof	External Air Temperature (°C)
Maximum	50,9	57,8	48,6	45,0	26,7	34,0
Average	32,9	35,9	25,6	31,8	22,1	27,1
Minimum	8,5	9,5	9,5	11,5	17,5	12,7
(ter amplit)	42,5	48,4	39,1	33,4	9,2	21,4

Source: Vecchia (2005)**.**

The results obtained by Peralta (2006) in his experiment with a prototype of several types of roofs corroborate the study by Vecchia (2005), who verified in a summer period the average maximum atmospheric temperature of 34.67°C and the average minimum of 21.16°C, and that the surface temperatures of the ceramic tile reached a maximum of 45.65°C and a minimum of 20.09°C. For these same atmospheric temperatures, it was verified for the fiber cement tile maximum and minimum temperatures of 48.99°C and 20.05°C, respectively.

Morais (2004) developed a study in which he verified that the solar rays that reflected on a green roof, 13% were transmitted to the ground, 27% were reflected and 60% were absorbed by the plants, demonstrating that the thermal performance in the summer, with green roof, reduced the heat flow by 20% due to photosynthesis and evapotranspiration, complementing Akutsu et al. (2005), that the surface temperature of the roofing system directly influences the internal temperature of the environment.

Another benefit offered by green roofs in buildings is energy savings, improving the energy performance of buildings, especially in summer. This technology can be identified as a passive cooling technique with high thermal inertia that attenuates the thermal loads of solar irradiation (MUTANI, et al. 2020). Albuquerque (2019) in his research mentions that the green roof helps to keep the ambient temperature stable inside the building, making the use of air conditioning and other cooling and heating equipment unnecessary. This is due to shading and evapotranspiration, cited by Morais (2004), which reduces the passage of heat, adding thermal insulation and, consequently, saving energy. Albuquerque (2019) also highlights that in order to reduce energy consumption, the structural design of the eco roof, the climate of the region and some properties of the building or house in which the roof will be installed must be taken into account. This privilege is not only given in the summer, but also in the cold, keeping the temperature more pleasant.

Thus, in his work, Baldessar (2012) concluded that if green roofs were more used, the energy expenditure for conditioning the environment would greatly decrease, because 45% of the energy consumed in Brazil goes to residential, commercial and public buildings where these have thermal performance contrary to green roofs whose performance is significant in terms of energy savings and thermal insulation.

As an example, Pendiuk (2017), in a study carried out in Singapore, in a building with a green roof, based on a normal roof, resulted in a passage of less than 10% of heat and, in another record, showed that in Madrid, in the summer, the energy consumption of an air conditioner in a building with a green roof was reduced by 6%.

Heat island, according to Albuquerque (2019), is a much hotter region than the other regions in its vicinity. Heat islands arise particularly when areas of vegetation are covered by concrete, asphalt, etc. These materials used in constructions, both in the ground and in the roofs, absorb the heat of the day and dissipate it during the night, causing a mass of heat to flatten over the cities. The temperature difference between urban centers and rural areas can reach 10ºC. Considering the green roof, in addition to reducing the impacts of the heat island and the emission of greenhouse gases, it has the property of absorbing and releasing part of the solar radiation, reducing the air temperature and increasing the air humidity, as a result of evapotranspiration.

Green roofs are increasingly popular around the world. In urban areas, they offer a number of benefits, including rainwater retention, building cooling, and promoting biodiversity (OBERNDORFER et al., 2007; BERARDI et al., 2014; FILAZZOLA et al., 2019, cited by HENK, 2020).

Bearing this in mind, if green roofs were installed in large quantities in Brazil, in large urban centers, there would be a possible reduction of the heat island effect, since its application has a beneficial result, softening the temperature and improving the quality of people’s lives.

The problem is that the large urban centers present a great densification of built areas with extensive surfaces of impermeable soil, causing the decrease of the natural soil and hindering the infiltration of rainwater. The public drainage system is overloaded in the intense rainfall, resulting in flooding of streets and flooding of rivers that directly affect the life of the urban population, where green roofs can contribute to the reduction of floods and restore the urban hydrological balance (PEREIRA , 2017).

In the face of the large amount of rainwater, in different parts of the world, one of the economically and environmentally viable alternatives is green roofs, since they help to retain this rainwater through their layers that absorb significant amounts of precipitation, thus reducing the runoff of rainwater.

In the UK summer scenario, Kemp (2019) demonstrated that green roofs can mitigate the risk of flooding by reducing the volume of surface runoff through direct interception and subsequent evapotranspiration.

Machado (2017) clarifies that in urban centers, the volume of noise exceeds the appropriate levels for human beings, causing discomfort to the population and harming hearing, and that with traditional coverings, sound waves expand. However, these sound waves are absorbed with plants and the environment substrate, significantly reducing noise.

The use of vegetative cover on roofs or conventional slabs is part of a list of initiatives to minimize global warming. Then, due to the vegetation applied on the cover, the process of photosynthesis takes place, purifying and filtering the air around it, thus carrying out carbon sequestration (MACHADO, 2017). He also adds that this process performs acoustic insulation, reducing the sound frequencies inside the buildings, serving as a sponge absorbing water and attracting a biodiversity of small animals.

In the words of Renterghem (2017), green roofs are able to reduce sound exposure near or inside a building, mitigating diffractive sound waves over (parts of) roofs and reducing sound transmission through the roof system. Jesus (2018) confirms this by saying that plants reduce noise by absorbing sound energy into movement and caloric energy, reflection and deflection or dispersion. A green roof with 12 centimeters of substrate can reduce sound transmission by up to 40db.

Thompson et al*.* (2008) explained in their work that the use of the green roof increases the useful life of the roofing system, because it protects the waterproofing layers from ultraviolet rays and extreme temperature variations, which are determining factors for its degradation. Ching (2010) corroborates Thompson et al*.* (2008) is statement, as he stated that the green roof protects the waterproofing layer, unlike traditional roofing. Therefore, they mention Guedes et al. (2019), that a common roof has a useful life of about 25 years, and a green roof lasts, on average, 50 years. That is, twice this time and the roofs on hot days can reach a temperature of 65.2 degree-hours of heat, above the air temperature.

Regarding insects and birds, the green roof works as an ecosystem reinforcement. A desired result of any construction project, according to Baldessar (2012), would be a landscape and an ecosystem that are regenerated and improved as a consequence of the project. By using plants native to the region, where the green roof is located, it is easier to restore the presence of native life. Perez et al*.* (2018) clarify that green terraces can be used as recreation and leisure areas, offering havens of peace and tranquility above traffic noise and immediate air pollution, and that the provision of green space at the roof level creates opportunities for community cohesion and improvements in health and well-being. They provide opportunities for leisure and coexistence, in addition to the aesthetic appeal of this type of coexistence, helping to improve quality.

METHODOLOGY

Bibliometric analysis

The bibliographic survey was carried out by approaching the focal theme. This method consists of reading published material (books, articles and others), increasing the initial knowledge about the subject, as well as the determination of indicators for the development of the bibliometric study. Bibliometric analysis allows the researcher to approach the object of study, as well as allows the statistical analysis of academic literature, from different perspectives (LIU, 2019). This method employs a quantitative approach, which gives quality to the description, evaluation and monitoring of scientific production (ELLEGAARD et al., 2015; LÓPEZ et al., 2019). The main laws governing bibliometrics are focused on the scientific productivity of authors, of journals and on the productivity of journals and word frequency. The bibliometric study is applicable to several science areas, commonly used to obtain indicators of scientific production, demonstrating the behavior, development and trend of a certain area of knowledge.

Data collection was carried out on March 14, 2022, using the scopus database, searching for scientific documents published between 2005 and 2022, using the Capes Periodicals Portal platform. Indicators related to green roofs, environmental protection and sustainability were used in order to investigate how the scientific community has been dealing with this theme. The query was applied to the title, abstract and keywords, using the indicators 'Court of justice', 'Green roofs', 'Sustainability'.

For the deepening of bibliometrics, 56 documents found on the *scopus* search site were used, a scientific database that gathers information about scientific studies, using the Boolean operators 'OR' and 'AND'.

For the bibliometric analysis of the documents related to the indicators researched, the VOSviewer software developed by Van et al. (2010) was used, a free program used to build maps (clusters) based on networks, using data cluster mapping techniques. The Vosviewer software was used as a tool to build bibliometric networks for citation of documents, journals, co-authorship of authors and co-occurrence of keywords.

The analysis of the scientific productions surveyed content focused on The Court of Justice of Pernambuco, identifying aspects of the research and current issues addressed, based on the history of publications. The global illustration of the methodology can be seen in Figure 4.

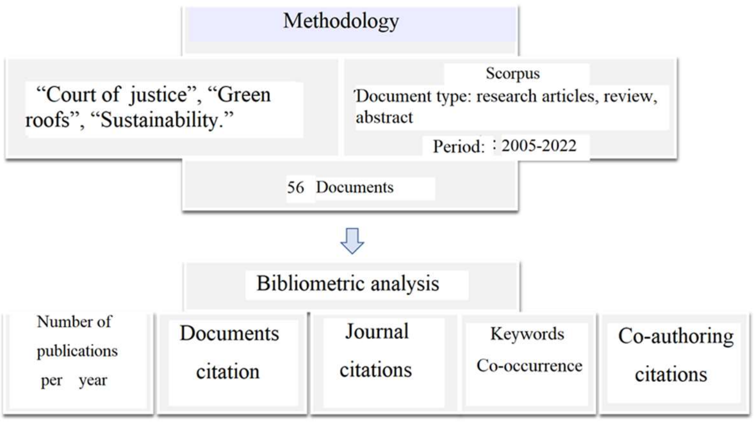

Figure 4: Fluxogram of the bibliometric analysis methodology.

RESULTS AND DISCUSSION

Bibliometric analysis

Publications per year analysis

It can be identified, through Figure 5, an increase in the number of publications on the 'green roof' theme. The increase of academic interest in this area was probably intensified by the imminent need to adapt work environments to the new reality of sustainability and environmental protection.

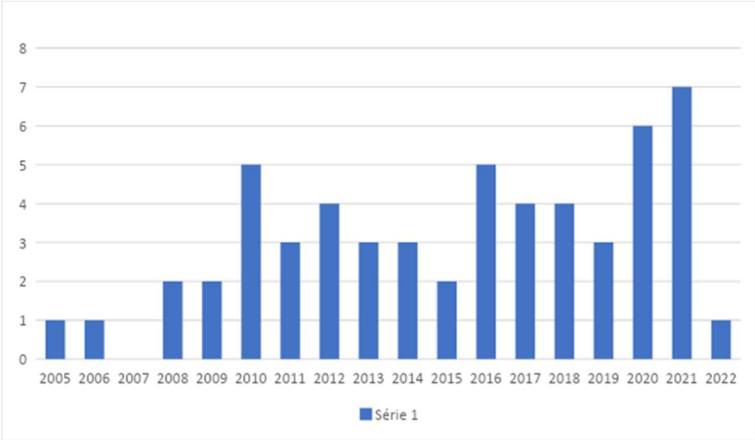

Figure 5: Green roof publications, from 2005 to 2022.

The scientific productions related to green roofs demonstrate the evolution of this topic, reaching its maximum peak in the year 2021.

Bibliometric document citation network

Figure 6 shows the number of scientific publications registered in Scorpus through the thematic axis of the study, reaching a total of 39 documents. Of this total, using the filter of 1 citation per document.

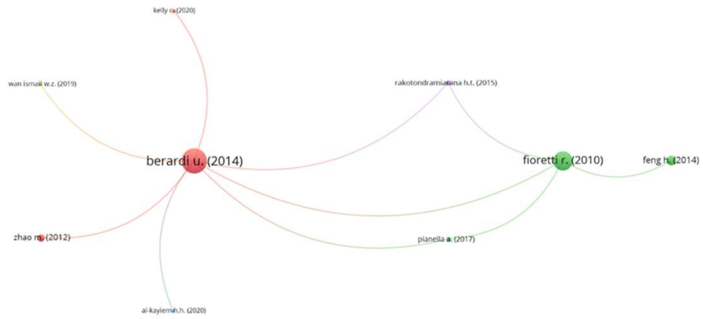

Figure 6: Documents citation.

The 5 most cited documents were Berardi (2014), Fioretti (2010) Feng (2014), Radic (2019) and Weinmaster (2009) (Table 3).

Table 3: Most cited documents ranking.

Ranking	Title	Author (year)	Citations Number	Journal	Cluster
1º	State-of-the-art analysis of the environmental benefits of green roofs	Berardi (2014)	402	Applied energy	**1**
2º	Green roof energy and water related performance in the Mediterranean climate	Fioretti (2010)	237	Building and environment	**2**
3º	Energy saving performance of green vegetation on LEED certified buildings	Feng (2014)	62	Energy and buildings	**2**
4º	Green facades and living walls-A review establishing the classification of construction types and mapping the benefits	Radic (2019)	45	Sustainability	**4**
5º	Are green walls as "green" as they look? an introduction to the various technologies and ecological benefits of green walls	Weinmaster (2019)	38	Journal of Green Building	**4**

The most cited document was Berardi (2014), entitled "*State-of-the-art analysis of the environmental benefits of green roofs*" belonging to Cluster 1, with 402 citations, published by Applied Energy (Table 4). The second most cited document was by Fioretti (2010), entitled "*Green roof energy and water related performance in the mediterranean climate*", cited 237 times, published by Building Environment. The third most cited document was by Feng (2014), from Cluster 2, entitled "*Energy saving performance of green vegetation on LEED certified building*", with 62 citations and published in the journal Energy and Buildings. The fourth most cited document was Radic (2019), entitled "*Green facades and living walls: A review establishing the classification of construction types and mapping the benefits*", with 45 citations and published by Sustainability. The fifth most cited article was Weinmaster (2019), entitled "*Are green walls as "green" as they look and introduction to the various technologies and ecological benefits of green walls*", with 38 citations and published by the Journal og green building.

Bibliometric network of journal citations

The most important journals in the research area were *Applied Energy*, *Building and Environment*, and *Energy and Building*, presented in Figure 7 and Table 4.

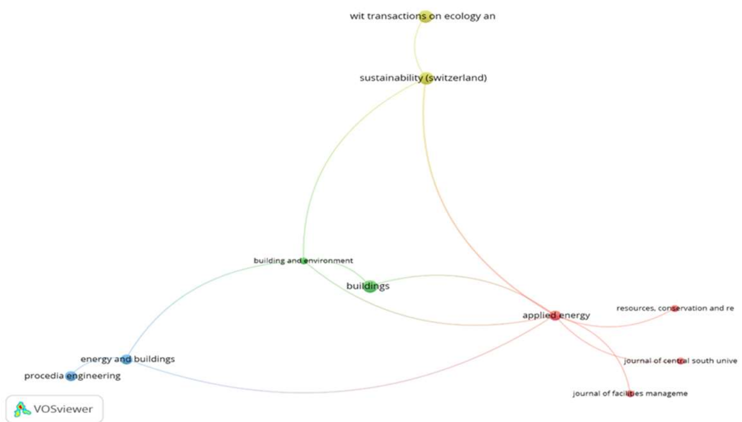

Figure 7: Journal citations**.**

Table 4: Ranking of journal citations.

Ranking	Journal	Number of documents	Number of citations	Cluster
1º	Applied Energy	2	402	1
2º	building and environment	1	237	2
3º	Energy and building	2	91	3

Bibliometric network of co-authoring

The bibliometric co-authoring network was applied to analyze the authors' cooperation pattern, based on 56 documents, with contributions from 146 different authors, of which only 9 authors have a co-authorship cooperation relationship in the studied research area (Figure 8).

Table 5 lists the co-authors who stood out the most in terms of number of documents and citations, based on Figure 8, through the thematic axis of the study, were **Fabbri**, **Barbieri** and **Tronchin**.

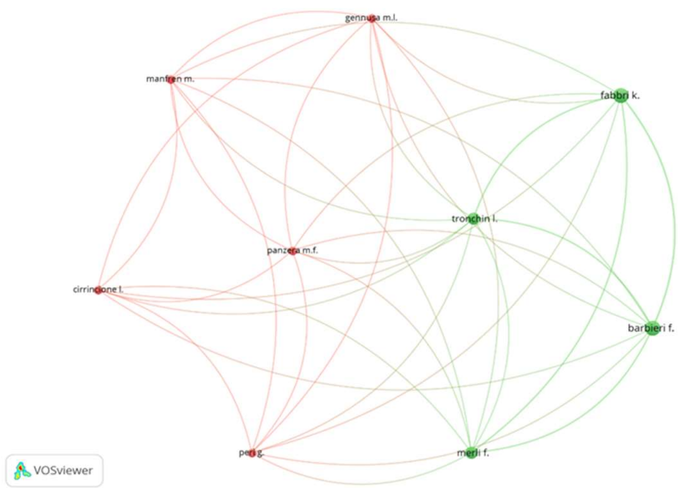

Figure 8: Co-authoring citations.

Table 5: Ranking of co-authoring citations.

Ranking	Author	Number of documents	Number of citations	Cluster
1º	Fabbri	3	5	2
2º	Barbieri	3	5	2
3º	Tronchin	2	4	2

Bibliometric network of keywords

The keywords most used by the authors were identified and analyzed to classify the 56 documents that were part of the sample. From this analysis, the themes that appear most frequently in a given area stand out. The bibliometric map represented in Figure 9. The keywords with the highest frequency were Green Roof (blue cluster), Sustainable Building (red cluster), Sustainability (light blue cluster) and Energy (blue cluster).

Figure 9: Co-occurrence citation.

Of the 56 documents, 192 keywords used by the authors were identified. Of these, 192 keywords appeared more than once (Figure 9). Table 6 presents the keywords that had the highest frequency. The keyword ‘Green roof’ occurred 22 times, being the most used word to summarize the main theme of the analyzed articles, followed by ‘sustainable building’ with 13 occurrences, ‘sustainability’ with 4 occurrences, and ‘energy’ with 26 occurrences.

Table 6: Keywords ranking.

Ranking	Keywords	Frequency	Cluster
1º	Green roof	22	3
2º	sustainable buildind	13	10
3º	sustainability	4	6
4º	energy	2	3

The scientific community is researching on green roofs, for which it used bibliometrics, identifying that the green roof brought benefits, so that it will be a new trend in studies. It was possible to identify an increase in publications, since the academic interest in this area arises as an idea to minimize the impacts caused to the environment.

In the last two years, the scientific production on the subject has increased publications, and it can be observed that Berardi (2014) with 402 citations, Fioretti (2010) cited 237 times, Feng (2014) with 62 citations, Radic (2019) with 45 and Weinmaster (2019) with 38 citations, were the ones who published the most about green roofs. The keywords indicate the direction of scientific productions on the addressed topic, which will help to discover mechanisms that can improve performance by suggesting innovative practices.

CONCLUSIONS

The work at issue aimed to show that the studies made of green roofs, made it possible to understand that its use in urbanized areas can be of fundamental importance as a way of preserving the environment and reducing the impacts caused by human actions.

The green roof consists of a vegetative coverage applied to the roof of a building, consisting of several layers that perform different functions. The green roof is capable of having a strong impact on any environmental certification system as, unlike other technologies, it acts simultaneously on several sustainability axes.

Thus, in addition, the harmonious analysis of the environmental, social and financial impacts that are connected, showing a greater feasibility for their implementation in the Judiciary of Pernambuco, and it can also be verified by the analysis that the members of the Sustainability Commission of the TJPE proved to be satisfied with the possibility of implementing new sustainable technologies such as green roofs in the TJPE, for the generated benefits.

Regarding the bibliometric analysis, it appears that the scientific production related to the indicators of green roofs evolution fluctuated by stability, discrepant in comparison to the 2020 year and reaching the maximum peak in the 2021 year. As expected, it shows the greatest importance with sustainability, the green roof being an important source for the preservation of the environment.

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