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Overview of publications on green roof: socio-educational possibilities and community strengthening

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ABSTRACT
Goal. Identify and present an overview of publications on green roofs, as well as verify and analyze their use in buildings of social interest and in association with socio-educational processes and community strengthening. Methodology. Integrative review, based on “Periódicos Capes, *Scielo* e *Ebsco”*, using “green roof”, “living roof” and “green roof” as descriptors, from 2012 to March/2023. Originality/relevance. It sought to update what has been published about green roofs and recognize possibilities of producing new knowledge on the subject, in a collaborative way, directly involving different social actors. Results. A total of 62 publications were analyzed, most by researchers in civil engineering, architecture, urbanism and environmental sciences, developed mainly through experimental field research. The topics were varied, with emphasis on studies on rainwater management, thermal performance, public policies, building structure, technical and economic feasibility. Regarding the use of green roofs in buildings of social interest, teaching institutions, social spaces, housing of social interest and rural settlements were cited, and in the latter, the research encouraged the integration of knowledge through the appropriation of techniques by residents. Theoretical/methodological contributions. The panorama presented contributes to the identification of scientific, theoretical and methodological gaps on the subject, and can help and stimulate new studies. Social and environmental contributions. It highlights the importance of locally-based research, especially in the constructed urban setting, aimed at sustainability, community strengthening and the exercise of citizenship.
KEYWORDS: Green roof. Integrative review. Empowerment.

1. INTRODUCTION

When thinking about contemporary environmental issues, the climate emergency and its effects are one of the most relevant. For many people, the first term that comes to mind is global warming and, as a result, a large part of society ends up associating it only on a planetary scale, that is, as something far from us. However, emergency and climate change can also have origin and effects at regional and/or local levels (ROMERO et al., 2019).

One of the main phenomena associated with climate change, in this local scale context, is the formation of Urban Heat Islands (ICU)s. The ICUs are characterized by higher temperature, lower relative humidity and changes in wind patterns and rainfall regimes, in relation to geographically equivalent areas, but which preserve the natural landscape. They are caused by urban densification, since the built mass blocks the circulation of winds, increases the surface area for absorbing solar radiation, makes the soil less permeable and reduces evapotranspiration by removing the vegetation cover (ROMERO et al., 2019).

A report by BBC News – Brazil, from October 11, 2021, entitled *The simple solutions to not 'die of heat' in India*, showed the work of a housing association in the city of Amedabad, which helped people to cool their homes. The temperature inside some residences in this city could reach 50^{O}C. For this reason, this housing association provided loans of 10,000 rupees (approximately R$ 619.00 reais – exchange rate on 06/04/2023) with an interest rate of 10% for the purchase of white paint. The objective was to apply the paint on the concrete slabs that covered the residences, which would contribute to the reduction of heat absorption by the concrete, considerably lowering the temperature, both inside the residences and on the slab itself (LOPES *et al.*, 2011). The concrete roof slab of these houses was, according to the news, often used as a bedroom on hot nights.

In Brazil, it is quite common to use fiber cement roofs to cover buildings, mainly in low-income housing and public buildings in low-income areas. Fiber cement roofs, however, are characterized by a high capacity to absorb heat, causing an increase in the temperature inside buildings. In another direction, external coatings with low absorption of solar radiation, greater reflectance, help to reduce the volume of heat transferred to the internal environment, in addition to reducing the occurrence of heat islands if the urban scale is considered (LOPES *et al.*, 2011).

In this sense, a possible solution is the application of "cold" paints in place of conventional paints. However, this alternative also requires special care, because paints, as well as other types of coatings on external surfaces, are exposed to all kinds of weather, therefore, more susceptible to degradation, both of the paint itself and of the material where it is applied. (CHAI *et al.*, 2011). The durability of a paint in general depends on a series of variables, such as: its composition, the characteristics of the material where it is applied, the environmental conditions and the care practiced by the user (LOH *et al.*, 2011). Cold paints, as well as conventional ones, also need periodic maintenance, which includes cleaning and repainting, because their degradation influences both the appearance and the ability to reflect solar radiation (SILVA, 2016).

Thus, this report draws attention to the possibility of finding alternative solutions, including from the integration of popular knowledge to technical-specialized knowledge, to face socio-environmental issues (GIATTI *et al.*, 2021), such as those related to thermal comfort.

Among these alternatives, this work highlights the "implantation" of vegetation, the so-called green roofs, on the coverage of residential, business, community, school spaces, etc., a practice already well recognized in the literature for its benefits to thermal comfort (MICHELS, 2018). It is also known that better results have been found when sustainable practices occur in a participatory way, in association with socio-educational processes, meeting the real demands and interests of those involved (SANTOS, *et al.*, 2011).

1.1 Green roof

The green roof, also known as green roof or living roof, has been increasingly used to, among other things, contribute to minimizing the thermal discomfort of buildings. It is a constructive system based on the implantation of a vegetable covering on the roof of buildings - both slabs and roofs - using waterproofing and drainage systems (RANGEL; ARANHA; SILVA, 2015).

Green roofs work on two scales, the building and the urban fabric. At the scale of the building, its main function is to improve thermal comfort. According to Carvalho et al. (2018), placing a green roof over a fiber cement roof leaves the internal temperature of the building around 23OC lower than a witness roof, only with fiber cement covering. At the urban scale, green roofs help to retain rainwater - rain simulations have shown retention of up to 56% of the precipitation volume - minimizing some of the impacts of urbanization on hydrological cycles, and reducing the formation of heat islands.

Oliveira (2009) cites other benefits of implementing green areas on built surfaces, such as retention of particulate matter in suspension; the decrease in temperature below the vegetation cover, resulting in energy savings; noise absorption; the increase in the useful life of the roof, compared to the same type of roof without the vegetation; the increase in the relative humidity of the air; the reduction in the peak volume of water to which the storm sewer system is subjected; and the psycho-emotional comfort caused by the presence of green areas. The author divides green roofs into accessible and inaccessible. The accessible ones constitute an area open to the circulation of people, functioning as a terrace-garden. The inaccessible ones do not support the circulation of people, but can either be flat, curved or inclined. They can also be divided into intensive, semi-intensive and extensive, whose division is based on the greater or lesser need for maintenance.

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Green roofs can be implemented both in new and pre-existing buildings, requiring only minor adaptations, as explained in the Hidrocidades Project, which was developed at the Professor Teófilo Moreira da Costa Municipal School, in the city of Rio de Janeiro, RJ, in region of Baixada de Jacarepaguá. Through integrated actions of social inclusion and citizenship, it aimed, among other aspects, at the conservation of water resources in the urban and peri-urban environment, from the perspective of integrating urban planning with the management of water resources (OLIVEIRA, 2009).

The green roof system chosen for this experiment was the extensive one, precisely because it requires little or almost no maintenance. The strategy involved dividing the school's roof into two symmetrical parts. One remained unaltered as a “control case” (or witness) and, in the other, planting was carried out. In addition to the appropriation of all the materials used, different species for cultivation on the roof were tested. The species Senico confused (Daisy), Asparagus densiflorus (Cat's Tail Asparagus), Tradescandia pallida (purple heart) and Portulaca grandiflora (Eleven-hours) were the species that presented the best results of adaptation to cover planting. The experiment also involved, through remote monitoring, a study on environmental thermal comfort and analysis of rainwater retention. The irrigation system was used to simulate rainfall on the roofs. Finally, the costs for implementing a green roof in social housing were inferred. It should also be noted that the research was carried out in a participatory manner, following the principles of action research, which is an empirical method in which researchers work together in a cooperative/participatory manner with representatives of the community where the problem situation occurs (OLIVEIRA, 2009).

Inspired by the project developed by Oliveira (2009) and, based on the good results obtained by the author, it is intended to seek and analyze other research on green roofs, as well as on the potential of projects for the implementation of these green roofs in association with actions of nature socio-educational, with direct participation of social groups involved, from the perspective of sustainability. The implementation of green roofs seems to be an opportune component in actions that integrate social inclusion, citizenship and education together with spaces of social interest.

2 OBJECTIVES

The present work aimed to identify and present an overview of scientific productions on green roofs, as well as to verify and analyze its use in buildings of social interest and in association with socio-educational processes and community strengthening.

3 METHODOLOGY

This is an integrative bibliographic review (SOUZA; SILVA; CARVALHO, 2010), carried out by searching for publications in the electronic databases Periodicals Capes, *Scientific Electronic Library Online* (Scielo) and *Ebsco Information Services* (Ebsco), using the descriptors “green roof”, “living roof” and “green roof”, from 2012 to March 2023.

For this survey and analysis of publications, we started with the following questions: What has been published in the scientific literature on green roofs? How is this socio-environmental technology being used? Have green roofs (or living roof, green roof), from a

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sustainability perspective, been used as a socio-educational and community strengthening strategy? if so, in what way?

Publications in which the term “green roof” was associated with vegetation cover, but not as a green roof or living roof practice, were discarded.

The descriptive analysis of the publications identified and selected for the construction of the panorama was carried out based on their reading and presented in the form of graphs and charts. This panorama presents the year, areas of knowledge and themes associated with the publications, responsible university, types of studies and/or uses, main objectives, and even if the study or use of the green roof technique was related to buildings of social interest and if was concerned with community strengthening, based on the appropriation of the technique, in association with socio-educational processes, with a view to sustainability.

4 RESULTS AND DISCUSSION

In the electronic databases investigated and in the defined period, in a search carried out in March 2023, using the descriptors “green roof”, “living roof” and “green coverage” alone, 119 publications were identified, as shown in Table 1.

Table 1 - Number of scientific productions found, according to the database, search descriptors, published from 2012.

Descriptors	Capes periodicals	science	Ebsco
Green roof	76	7	10
living roof	2	0	1
green roof	17	2	4

Source: The authors

Of these, 62 publications were considered for full reading and analysis (Table 2). The others were discarded because they were repeated in the electronic databases or because they were outside the scope of this research, for example, when they spoke of green coverage, but not as coverage/roof of buildings.

Table 2 - Publications selected for the construction of an overview on green roofs and for analysis.

Nº	Articles
01	WATANABE, R.T.I.; HONDA, S.C.A.L. The green roof in buildings. Colloquium Exactarum, n.8, p. 74-79, 2016.
02	DURANTE, L. C.; ALENCAR, S.G.; VENERE, P.C.; CALLEJAS, I.J.A.; RABELO, O. S.; ROSSETTI K.A.C. Ecological coverage for application in housing in agrarian reform settlements: eco-innovation alternatives. E&S Engineering and Science, v.8., n.1, p. 41-61, 2019.
03	STAHLHÖFER, I.S.; CUSTÓDIO, A.V. Green roofs as an expression of local power in the formulation of a public policy front mitigating urban-environmental damage. Revista da Faculdade de Direito – UFPR, v.59, n.1, p.127-143, 2014.
04	BALDO, M.S.; BRENNER, B.L.; KERN, A.P.; GONZALEZ, M.A.S. Comparison between the thermal behavior of extensive green cover and fiber cement cover in the climate of São Leopoldo city, Brazil. AIDIS Journal of Engineering And Environmental Sciences, v.13, n.2, p.273-278,
05	FREITAS, JR, J.A.; SANQUETTA, C.R.; IWAKIRI S.; COSTA, M.R.M.M.; KOEHLER, H.S. Study of the application of green roofs in order to build carbon neutral buildings. Holos Environment, v.17, n.1, p. 35-52, 2017.
06	STAHLHÖFER, I.S.; PEREIRA, M.F.B. Public policies for the implementation of green roofs: Bill No. 115/2009 of the City Council of São Paulo. Electronic Journal of the Law Course – UFSM, n.8, p.386-98, 2013.
07	FRANCO, M.A.M.; SOUSA, J.S. Sustainable constructions: applications for the city of Uberaba —MG. Journal of Environmental Management and Sustainability, v.9, n.1, p. 1-24, e16205, 2020.
08	BONIFÁCIO, T.P.S.; ROMERO, M.A.B. The analysis of the urban environmental sustainability of the central areas of the city of Taguatinga. Paranoá: Cadernos de Arquitetura e Urbanismo, v.14, p.19-27, 2015.

09	SILVA, E.R.A. Urban agriculture management. International Journal of Sciences, v.4., n.1, p.17-47, 2014.
10	ROSSETI, K.A.C.; DURANTE, L. C.; CALLEJAS, I.J.A.; NOGUEIRA, M.C.J.A.; NOGUEIRA, J.S. Systemic approaches to the effects of the implantation of vegetated roofs. Braz. Geoghaphical J. Geosci. Humanit. Res. Medium, v.4, n.1, p.55-77, 2013.
11	SALEIRO FILHO, M.O.; REIS-ALVES, L.A.; SCHUELER, A.S.; ROLA, S.M. Beyond a reserved dialogue with the stars: the formation and transformation process from the garden terrace to the green roof. RCT - Journal of Science and Technology, v.1, n.1, 2015.
12	MACHADO, N.A.L.; GONZALEZ, C.G.D.; MENDEZ, W.B.N.; MACHADO, L.J.L.; PUGO, M.G.S.; ACEVEDO, R.X.L.; MACHADO, V.V.M. Rainwater storage in urban environments using green roofs. La Granja: Life Sciences Magazine, v.32, n.2, p.54-71, 2020.
13	OHNUMA JR, A.; ALMEIDA NETO, P.; MENDIONDO, E. Analysis of water retention in green roofs based on the efficiency of the runoff coefficient. Brazilian Journal of Water Resources, v.19, n.2, p. 41-52, 2014.
14	KOCK, R.V.; THEISS, V.; PARIZOTTO FILHO, S. Economic and financial analysis of the use of vegetated roofs in public buildings. Navus, v.11, p. 1-17, 2021.
15	LIZ, D.S.; ORDENES, M.; GUTHS, S. Experimental analysis of the thermal behavior of the extensive green roof for Florianópolis. Oculum Essays, v.15, n.2, p. 315-33, 2018.
16	PAVANATE, A. L.; FLEISCHFRESSER, L. Seasonal analysis of surface winds using an automatic meteorological station. Revista Brasileira de Geomática, v.5, n.2, p. 291-305, 2017.
17	GALLARDO, N.P.; ALVES, E.D.L.; SILVA, M.S.D.; SOUSA, F.L.N.; SANTOS, B.C. Evaluation of comfort and thermal efficiency in buildings with plant environments: an experimental study report. Brazilian Journal of Management and Regional Development, v.17, n.2, p.365-380, 2021.
18	FRANCO, B.M.; ANDRES, C.M.; KONRAD, J.; TASSI, R.; LIBERALESSO, T. Evaluation of rainwater runoff in green roof modules with different substrates. Acta Brasiliensis, v.3, n.2, p. 69-73, 2019.
19	CARVALHO, G. C.; TONELLO, P.S.; MIRANDA, J.H. Evaluation of green roof systems: thermal analysis in different systems cultivated withCallisia Repens. Brazilian Journal of Environmental Sciences, n.49, p. 66-80, 2018.
20	MORUZZI, R.B.; MOURA, C.C.; BARBASSA, A.P. Evaluation of the effect of slope and antecedent humidity on the quality and quantity of drained, percolated and stored plots in an extensive green roof. Built Environment, v.14, n.3, p. 59-73, 2014.
21	RODRIGUES, G.C.; SANTINI JR, M.A. Evaluation of the use of compensatory techniques in the Ribeirão do Santa Rita urban sub-basin in the municipality of Fernandópolis, São Paulo. Sanitary and Environmental Engineering, v.26, n.2, p. 231-37, 2021.
22	NUNES, D.M.; SILVA, L.P.; FONSECA, P.L. Evaluation of the role of green roofs in low environmental impact urban design and development and in flood control in the city of Rio de Janeiro. Labor & Engenho, v.11, n.3, p. 374-393, 2017.
23	DUARTE, P.A.B. Bioprospecting of diazotrophic microorganisms as an alternative for soil improvement in the urban canopy of the EAN University. Ontare Magazine, v.4, n.1, p. 67-87, 2016.
24	MELO, A.B.; MENDONÇA, T.N. Cement blocks with EVA waste for extensive modular green roof: contribution of the components for thermal insulation. Revista IBRACON de Estruturas e Materiais, v.10, n.1, p. 92-121, 2017.
25	PESSOA, V G.; GUISELINI, C.; MONTENEGRO, A.A.A., PANDORFI, H.; BARBOSA FILHO, J.A.D., VICENTE, T.F.S. Carbon sequestration by plant species used in green roofs across different periods. Brazilian Journal of Agricultural and Environmental Engineering, v.26, n.6, p. 407-411, 2022.
26	POLZER, V. R. Composting: A need for urban centers. Brazilian Journal of Environmental Sciences, n.40, p. 124-136, 2016.
27	DREHER, A.R.; JACOSKI, C.A.; MEDEIROS, R. Concepts of bioclimatology and sustainability applied to the Project phase in Social Interest Housing. Magazine of the University of Vale do Rio Verde, v.14, n.1, p. 145-159, 2016.
28	CARNEIRO, T.A.; GUISELINI C.; PANDORFI, H.; LOPES NETO, J.P.; LOGES, V.; SOUZA, R.F.L. Primary thermal conditioning of rural installations through different types of coverage. Brazilian Journal of Agricultural and Environmental Engineering, v.19, n.11, p.1086-1092, 2015.
29	OHNUMA JR, A.A.; GOMES, M.M.; SILVA, L.P. Global effects of temperature and precipitation on green roofs. Brazilian Journal of Climatology, v.20, p. 234-251, 2017.
30	ALAMY FILHO, J.E.; MANNA, I.B.C.B.; MELO, N.A.; CAIXETA, A.C.M. Hydrological efficiency of green roofs for the scale of residential subdivisions. Society & Nature. Magazine of the Department of Geography – UFU, v.28, n.2, p. 257-272, 2016.
31	TEIXEIRA, C.A.; BUDEL, M.A.; CARVALHO, K.Q.; BEZERRA, S.M.C.; GHISI, E. Comparative study of the quality of rainwater collected on a roof with concrete tiles and on a green roof for non-potable uses. Built Environment, v.17, n.2, p. 135-155, 2017.
32	ALMEIDA, C.P.M.F.; CHAVES, J.W.R.C.; DANTAS, M.J.F. Study of the urban drainage system located on Avenida José Caetano de Almeida, Quixadá/CE. Tecnologia Magazine, v.41, n.2, p.1-17, 2020.
33	ARBOIT, N.K.S.; TASSI, R.; LIBERALESSO, T.; CECONI, D.E.; PICCILI, D.G.A. Green roof evapotranspiration rates and stormwater control under subtropical climate: a case study in Brazil. Revista Brasileira de Recursos Hídricos, v.26, p.1-17, e32, 2021.

34	SANTOS, P.L.F.; CASTILHO, R.M.M. Floriferous herbaceous and substrates for use on extensive green roofs. Ornamental Horticulture, v.24, n.3, p. 261-268, 2018.
35	RIONDET-COSTA, D.R.T.; SANT'ANNA, D.O.; ALEXANDRINO, S.A. Legal incentives for sustainable urban constructions. City Law Magazine, v.8, n.4, p.1381-1402, 2016.
36	VIEIRA, R.; ISENSEE, L.J.; CLAUDINO, G.O. Legal instruments as tools for reducing risks and disasters to floods. Redes, Santa Cruz do Sul, Brazil, v.25, n.4, p.1953-1972, 2020.
37	ROSSETI, K.A.C.; NOGUEIRA, M.C.J.A.; NOGUEIRA, J.S. Microclimatic interference in the use of green roofs in tropical regions: a case study in Cuiabá, MT. Electronic Magazine on Management, Education and Environmental Technology, v. 9, n.9, p. 1959-1970, 2013.
38	OHNUMA JR, A.A.; MENDIONDO, E.M. Methodology for calculating the efficiency of compensatory techniques in an urban lot. International Journal of Sciences, v.5. n.1, p. 29-41, 2015.
39	RANGEL, A.C.L.C.; ARANHA, K.C.; SILVA, M.C.B.C. Green roofs in environmental policies as an inducing measure for sustainability. Development and Environment, v.35, p. 397-409, 2015.
40	MORAIS, B.R.; MENDEZ-QUINTERO, J.D.; MACEDO, D.R.; NERO, M.A. Green roofs in environmental policies and as a mitigating measure for urban flooding. Labor & Engenho, v.15, p.1-12, e021018, 2021.
41	VIEIRA, N.L.; QUEIROZ, T.M.; FAGUNDES, M.C.; DALLACORT, R. Potential of utilization of rain water excess for irrigation of green roofs in Mato Grosso, Brasil. Engenharia Agrícola, v.33, n.4, p. 857-864, 2013.
42	HINNING, JP; ORIQUES, D.; HOLLAS, I.J. Green roof prototype: combining knowledge in favor of environmental education. Environmental Monographs, v.14, p.79-83, 2015.
43	ALMEIDA, S.C.; BRITO, G.P.; SANTOS, S.M. Historical review of green roofs: from Mesopotamia to the present day. Brazilian Journal of the Environment, v.2, n.1, p.42-51, 2018.
44	VIEIRA, Z.C.; SANTOS, S. C.; SILVA, G.B.; DANTAS, K.S.A.; ALBUQUERQUE, E.F. Simulation of the use of green roofs ready to mitigate urban floods: the Federal Institute of Education, Science and Technology of Sergipe as a case study. Tecnologia Magazine, v.39, n.2, p. 1-12, 2018.
45	AKWA, J.V.; PETRAGLIA, G.O.S.; LAUFFER, H.A.; SOARES, R.S. Simulation and analysis of methods for increasing the thermoenergetic efficiency of a building. UERGS Scientific Electronic Journal, v.3, n.1, p.171-193, 2017.
46	AZEVEDO, F.S.; SILVA, G.J.A.; SILVEIRA, J.A.R.; BARROS FILHO, M.N.M. Hydrological simulation of bioretention: efficiency analysis of compensatory techniques to mitigate impacts of urbanization. Sanitary and Environmental Engineering, v.27, n.6, p.1077-1088, 2022.
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48	CÁCERES, N.; IMHOF, L.; SUÁREZ, M.; HICK, E.C.; GALETTO, L. Assessing native germplasm for extensive green roof systems of semiarid regions. Ornamental Horticulture, v.24, n.4, p. 466-476, 2018.
49	COELHO, L.E.P.; OHNUMA JR, A.A.; FONSECA, P.L. Drainage rates from scenarios with compensatory green roof technique using the SWMM model. Latin America Water Management Magazine, v.19, e.24, p.1-15, 2022.
50	OSUNA-MOTTA, I.; HERRERA-CACERES, C.; LÓPEZ-BERNAL, O. Planted roof as a passive air conditioning device in the Tropics. Architecture Magazine (Bogotá, Colombia), v.19, n.1, p. 42-55, 2017.
51	WILLES, J. A.; REICHARDT, K. Technologies extensive green roofs: regional trade substrates most appropriate to the system. Revista Internacional de Ciências, v.4, n.2, p.2-12, 2014.
52	WHITE, S.Z. Green roof: from theory to feasibility of implementation at IFF Campus Macaé/RJ. Bulletin of the Alberto Ribeiro Lamego Environmental Observatory, v.16, n.1, p. 57-73, 2023.
53	COSTA, T. L.; REZENDE, L.H. Green roof of the Library of the Pontifical Catholic University of Minas Gerais: a technical and financial approach. Academic Path, v.9, n.17, p. 289-309, 2019.
54	SANTOS, P.T.S.; SANTOS, S.M.; MONTENEGRO, S.M.G.L.; COUTINHO, A.P.; MOURA, G.S.S.; ANTONINO, A.C.D. Green roof: performance of the building system in reducing surface runoff. Built Environment, v.13, n.1, p.161-174, 2013.
55	ALVES, J.J.A.; BEZERRA, C.W.F.; SILVA FILHO, R.V.; SOUZA, J.V.S.; CORDEIRO, J. A.; SILVA, L.F. Green roof and its thermal performance in homes in semi-arid regions. Magazine in Agribusiness and the Environment, v.14, n.4, p. 1-10, 2021.
56	TASSI, R.; TASSINARI, L.C.S.; PICCILLI, D.G.A.; PERSCH, C.G. Green roof: a sustainable alternative for rainwater management. Built Environment, v.14, n.1, p.139-154, 2014.
57	FRIZON, A.J.; LÁZARO, P.H.B.; KEMPTER, E.D.; CANTERAS, F.B. Green roofs as an alternative for sustainable buildings. Green Journal of Agroecology and Sustainable Development, v.13, n.5, p. 620-629, 2018.
58	SETTA, B.R.S. Green roofs as environmental public policies for the city of Volta Redonda - RJ. LABVERDE Magazine, v.8, n.1, p. 13-35, 2017.
59	PAULA, G.; FREIRIA, R.C.; CANTERAS, F.B. Green roofs in the context of sustainable cities: technical aspects and current environmental legislation. City Law Magazine, v.14, n.2, p. 948-975, 2022.
60	FERNANDES, V. C.; TONIAL, M.; FIORI, S.; SCORTEGAGNA, V.; GIL, A.S.L.; FERREIRA, M. C.; ADAMES, D.B. Green roofs: a contemporary perspective. Revista CIATEC-UPF, v.9, n.1, p. 46-57, 2017.
61	CASTILHO, R.M.M.; FREITAS, R.C.; SANTOS, P.L.F. The turfgrass in landscape and landscaping. Ornamental

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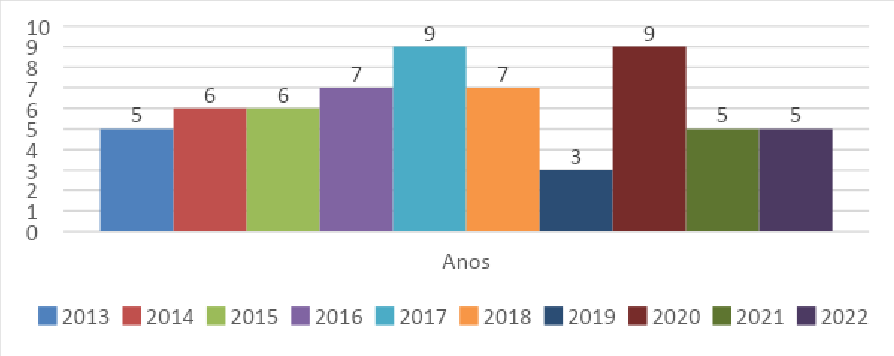
	Horticulture, v.26, n.3, p.499-515, 2020.
62	SOUSA, M.C.B.; PEDROSA, R.A.; IWATA, B.F.; CHAVES, S.V.V. Use of green roofs to control urban rainwater in Teresina - Piauí. Revista de Geografia, Recife, Brazil, v.38, n.2, p.148-163, 2018.

Source: The authors

About the year of publication, in the investigated period, from 2012 to March 2023, the largest amount is TASSI, R.; TASSINARI, L.C.S.; PICCILLI, D.G.A.; PERSCH, C.G. Green roof: a sustainable alternative for rainwater management. Ambiente Construido, v.14, n.1, p.139-154, 2014.va in the years 2017 and 2020, with 9 publications being found in each of these years. No publications from 2012 were found, and in 2019 only 3 were identified, as shown in Graph 1.

Graph 1 - Number of publications, per year, from 2012 to 2023.



Source: The authors

4.1 Areas of knowledge and institutions responsible for research on green roofs, presented in publications

We tried to recognize the areas of knowledge related to the research reported, based on the identification of the authors' training and/or institutional ties. Thus, research/publications were grouped into 9 categories of areas. In the category “civil engineering, architecture and urbanism”, as a direct or associated area, there was the largest number of publications, 32, followed by “environmental sciences”, with 23, as shown in table 3.

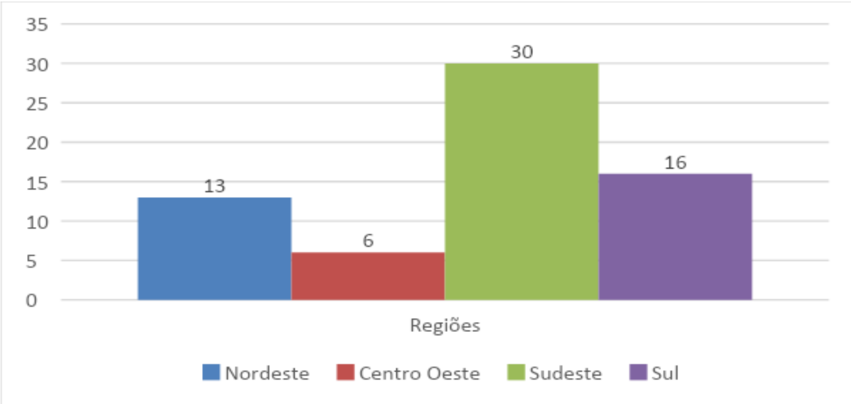
Table 3 – Areas of knowledge related to research reported in publications.

Area Categories	Amount
Civil engineering, architecture, urbanism: civil engineering (17); architecture and urbanism (9); buildings (2); urban and environmental engineering (1); urban environmental management (1).	32
Environmental sciences: environmental engineering (5); hydrology (4); sanitary engineering and environment (4); environmental management (3); environmental physics (2); environmental sciences (2); environmental systems (1); development and environment (1); climatology (1).	23
Agricultural/Agronomic Sciences: Soil Sciences (3); agronomy (2); agricultural engineering (2); production and agro-industrial engineering (1); soil physics and technology (1); plant production (1); food technology and socio-economics (1).	11
Right	4
Biological sciences: plant biology/phytotechnics (3).	3
Other engineering: transport engineering (1); mechanical engineering (1).	2
Geography	1
History	1
accounting sciences	1

Source: The authors

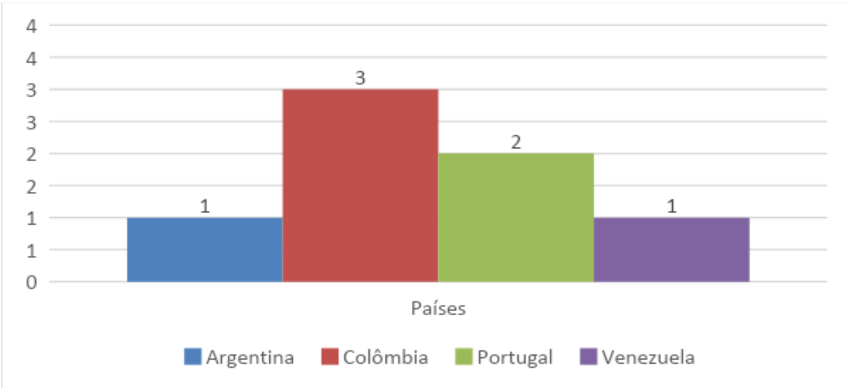
Regarding the institutions involved in the research reported in the publications, the majority, 54, were conducted by public institutions; 13 were private; and, still, 7 were foreign institutions. In one of the publications (STAHLHÖFER; PEREIRA, 2013), the research was conducted in partnership by a public and a private institution. Some surveys were developed by more than one institution, and there are also institutions that were responsible for more than one survey. For this reason, there are divergences in the total number of institutions involved in the research (whether public, private or foreign), and in the total number of institutions by region in Brazil. Graph 2 shows the location of these institutions, by region of the country, with emphasis on the Southeast, where 30 of the institutions were located, and the North region, from which no institution was mentioned. Graph 3 shows the countries of foreign institutions.

Graph 2 – Number of institutions involved in research, by region of the country.



Source: The authors

Graph 3 – Number of foreign institutions involved in research, by country.



Source: The authors

4.2 Types of studies presented in the publications, regarding the methodological approaches and/or mentioned uses of the green roof

The types of studies analyzed were grouped into the following categories:

i) Research of a theoretical nature and, therefore, developed from a bibliographic review and/or document analysis, as in the work of Morais *et al.*, (2021) which, through the search for publications in electronic databases (Scopus, Periódicos Capes e Scielo), in the last

15 years, presented a historical review of techniques and studies of management and urban planning for the installation of roofs green areas aimed at mitigating urban floods.

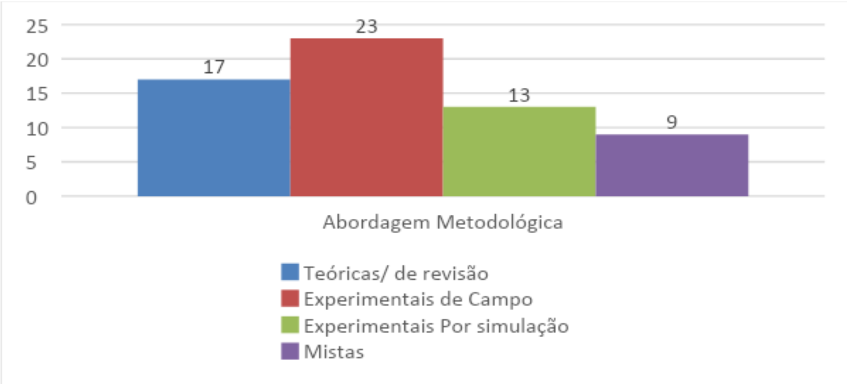
ii) Experimental field research, using, for example, the making of prototypes for analysis, as in the research by Carvalho, Tonello and Miranda (2018), which evaluated thermal comfort from different green roof systems.

iii) Experimental research carried out by simulation and/or case studies, as in the study by Nunes, Fonseca and Silva (2017), which used the hydrological-hydraulic computational model*Storm Water Management Model*, from the American Environmental Protection Agency (US-EPA SWMM), applied to the case of the Morto river basin, in the Baixada de Jacarepaguá, in the city of Rio de Janeiro, to virtually evaluate scenarios with and without green roofs, verifying their contribution in flood control, for example, by reducing the volume of rainwater drained off the surface.

iv) Mixed research, that is, those in which more than one technique, instrument or method were mentioned. In the study by Tassi*et al.*, (2014) associated an experimental model of modeling a green roof, surveys of climatological and rainfall data and long-term monitoring to assess its efficiency in controlling rainwater runoff.

The distribution and categorization of these publications, according to the methodological approach, are represented in Graph 4 below.

Graph 4 – Distribution of analyzed publications on green roof, according to methodological approach.



Source: The authors.

4.3 Featured topics associated with publications and main objectives

With regard to the themes associated with publications on green roofs, and their main objectives, research related to: the handling and management of rainwater and urban drainage, for example, to verify the performance of a green roof building system in reducing surface runoff (SANTOS *et al.*, 2013); thermal performance, evaluating, for example, different types of coverage, based on thermal analyzes and indices of human and zootechnical thermal comfort (CARNEIRO *et al.*, 2015); to public policies, whether for the implementation of green roofs, incentives and legal instruments (RANGEL; ARANHA; SILVA, 2015), or to verify whether the use of green roofs has complied with the requirements of urban environmental policies and services (PAULA; FREIRIA; CANTERAS , 2022); the possible interference of green roofs in the structure of buildings (FREITAS *et al.*, 2017); technical and economic viability (COSTA; REZENDE, 2019); energy or thermoenergetic efficiency (AKWA *et al.*, 2017); the analysis of the quality of rainwater, in terms of physical and chemical parameters, collected from green roofs

(TEIXEIRA et al., 2017); and the performance of some species of plants and substrates (SANTOS; CASTILHO, 2018).

There were also studies related to atmospheric pollution (SETTA, 2017), relative humidity around buildings (ROSSETI; NOGUEIRA; NOGUEIRA, 2013), landscaping (CASTILHO; FREITAS; SANTOS, 2020), composting (POLZER, 2016), agriculture (SILVA, 2014), capture/storage of CO_2 (PESSOA *et al.*, 2022), evapotranspiration (ARBOIT *et al.*, 2021) and the influence of climatic factors on green roofs (OHNUMA JR; GOMES; SILVA, 2017). And also more generic research on sustainable building technologies or with low environmental impact, which highlighted green roofs and roofs (RIONDET-COSTA; SANT'ANNA; ALEXANDRINO, 2016).

4.4 Green roofs for buildings of social interest, community strengthening and socio-educational processes

It was also sought, through this research, to identify the use of green roofs (or studies about it) in buildings of social interest and, also, publications that expressed concern with community strengthening and socio-educational processes, based on the roof technique. green. Of the 62 publications that made up this panorama, 10 brought this perspective.

Green roofs were suggested by Novais et al. (2020) for spaces at a university, in the city of Cuiabá, MT; by Osuna-Motta, Herrera-Cáceres and López-Bernal (2017) for social spaces in the city of Cali, Colombia; by Koch, Theiss and Parizotto Filho (2021) for public computer labs, in Florianópolis, SC; and by Dreher, Jacoski and Medeiros (2016) for social housing.

Durante *et al.* (2019) investigated possibilities of using ecological roofs, including the green roof, in housing in rural settlements for agrarian reform, which are usually built collaboratively, through joint efforts. However, these areas are often far from urban centers and, therefore, access to the materials needed for conventional roofing is more difficult and costly. Thus, in this publication, the authors, in addition to encouraging artisanal production, using cheaper materials available in the settlement area, encourage the appropriation of techniques by residents, integrating specialized knowledge with local popular knowledge.

This integration is also recognized by Stahlhöfer and Custódio (2014), in the perspective of transdisciplinarity and the convergence of different fields of knowledge for the formulation of public policies aimed at the implementation of green roofs in urban buildings. For the authors, the strengthening and exercise of local power and the recognition by citizens of demands for environmental conservation involves municipal public policies in line with local particularities.

Another study involved students from a Technical Course in Buildings, at Instituto Federal Farroupilha, Campus Panambi, RS, in the development of a green roof prototype. According to the authors, “the research carried out on sustainable alternatives aimed at civil construction and the development of the green roof prototype, seeks to interact with knowledge related to aspects of environmental education” (HINNING, ORIQUES and HOLLAS, 2015, p. 81).

The importance of broad studies on green roofs, aimed at locally based sustainability, is indicated by Franco and Souza (2020). The authors recommend that these are allied to “(...) building the awareness of the whole society about its vital role in changing the urban scenario” (p.22). In the same direction, Vieira *et al.* (2018), point out that the use of this type of coverage brings not only benefits at the individual level of buildings, but also collective ones when composing the urbanization of cities.

5 CONCLUSIONS

The construction of this panorama of publications on green roofs, in the period and electronic bases investigated, showed greater emphasis and interest in research of an exclusively technical nature, especially related to the management of rainwater and the thermal comfort of buildings, conducted and involving academic researchers, the which, of course, have great relevance. Fewer studies were identified, developed in association with participatory and socio-educational processes, with the cooperation, for example, of a lay public that, in some way, could benefit from this theoretical and/or practical learning.

Faced with current socio-environmental and health problems, it is considered that projects and research on green roofs, as "living" laboratories for teaching-learning and community empowerment, can be developed in an interactive and collaborative way between researchers, managers and technical professionals. from the public, private and third sector, high school and undergraduate students and interested lay public. It is suggested the development of workshops on technical skills necessary for the implementation of green roofs, from the perspective of education for sustainability and connected to local daily demands.

Thus, it is believed that participants in these investigative and socio-educational processes will be encouraged, both to produce new knowledge and to seek their own solutions, aimed at better living conditions in the built environment and urban setting of cities, and to demand from the public authorities, always where necessary, the adoption of more sustainable practices, especially in spaces and buildings of social interest.

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