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NATURE-BASED SOLUTIONS AND THE CHALLENGE OF BASIC SANITATION IN FAVELAS AND URBAN COMMUNITIES: AN ANALYSIS OF THE JARDIM NOVA ESPERANÇA FAVELA IN SÃO JOSÉ DOS CAMPOS-SP

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ABSTRACT

Brazil faces persistent inequality in access to basic sanitation, especially in vulnerable areas. According to the 2022 Demographic Census, about 50 million Brazilians live in households with precarious access to sanitary sewage services. The aim of this study is to investigate the feasibility of Nature-Based Solutions (NBS) as sustainable alternatives for sanitary sewage in slums and urban communities. The focus is on the implementation of decentralized systems that use natural processes and local technologies, aiming to meet the needs of these communities in a sustainable way, promoting environmental, social and economic benefits, always respecting ecological cycles. We adopted a dialectical approach and used the methodology of indirect documentary research, based on data from research institutes and bibliographic review. A case study was carried out in the Jardim Nova Esperança Favela, known as Banhado, in São José dos Campos-SP, considered a Smart and technological City. This community faces challenges of land irregularity and notable precariousness in basic sanitation. In the context of Sustainable Development Goal number 6 (SDG 6), created by the United Nations (UN) at the Millennium Summit in 2000, which aims to ensure universal and equitable access to safe drinking water and adequate

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sanitation by 2030, this study highlights how NBS can contribute to the improvement of sanitation conditions in vulnerable areas, aligning with the global sustainable development goals. The implementation of decentralized sanitary sewage solutions can directly contribute to the reduction of inequalities in access to sanitation and the mitigation of environmental and socio-spatial impacts in these territories. We conclude that NBS have the potential to expand access to sanitation in vulnerable areas, offering innovative and effective solutions to the problem. These alternatives promote social and environmental inclusion and reinforce the importance of decentralized sanitation models as strategies for more equitable and sustainable urban development.

Keywords: Basic sanitation, Nature-Based Solutions (NBS), Decentralized sanitary sewage, Jardim Nova Esperança Favela, Socio-spatial inequality.

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INTRODUCTION

Brazilian favelas and urban communities face serious shortcomings in terms of basic sanitation, especially in adequate sanitation. Many solutions adopted are precarious and improvised, such as black cesspools, open disposal or the direct release of waste into bodies of water (VIEIRA; VALÉRIO FILHO; MENDES, 2024). This scenario aggravates the spread of waterborne diseases and accelerates environmental degradation, profoundly affecting the social and urban conditions of these regions (HELLER, 2022).

In this context, Nature-Based Solutions (NBS) emerge as a sustainable and economically viable approach, especially in urban areas. These solutions use natural processes to create responses that benefit the environment, stimulate the local economy, and improve the quality of life of communities (FRAGA, 2020). In the urban scenario, NBS have gained relevance in planning, offering alternatives that align with the needs of vulnerable areas, such as favelas (IUCN, 2016, 2020).

Even with advances in sanitation, about 1.2 million people in Brazil still live without access to adequate toilets or sanitary facilities, performing their physiological needs in the open (IBGE, 2022). It is urgent to rethink the future of basic sanitation, with a focus on sustainability and improving the quality of life. Issues related to sanitation directly affect marginalized populations, demanding that scientific research contribute with analyses and recommendations for the reduction of social inequalities and the promotion of more dignified living conditions (PHILIPPI JR.; MALHEIROS, 2005).

Capitalist urbanization, guided by neoliberal principles, transforms urban areas into productive and profitable spaces, deepening socio-spatial segregation, especially in favelas and urban communities. Urban development policies, by prioritizing economic growth, tend to neglect marginalized communities, perpetuating inequalities. The lack of adequate basic sanitation reflects this territorial segregation, whose private interests override the rights of vulnerable populations, reinforcing the cycle of social exclusion (HARVEY, 2020).

The lack of adequate sanitary sewage directly affects the lives of residents, widening social disparities and hindering access to basic conditions of well-being (VIEIRA *et al.*, 2024a). Carlos (2017) analyzes urban deprivation and the concept of "right to the city", when he states that urban space is shaped by the logic of the commodity, which results in a city experienced as a source of deprivation and conflicts.

Given the relevance of basic sanitation for public health, quality of life and well-being, this study is justified by the need to apply innovative and efficient solutions in

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disadvantaged places (VIEIRA *et al*., 2024B). The implementation of Nature-Based Solutions (NBS) presents itself as an alternative to deal with the precariousness of sanitary sewage, meeting the social and environmental demands of these territories (VIEIRA et al., 2024c). In addition to promoting direct benefits, these solutions can strengthen community resilience and social inclusion, contributing, albeit partially, to the reduction of socio-spatial inequalities.

LITERATURE REVIEW

Nature-Based Solutions (NBS) were initially developed by the International Union for Conservation of Nature (IUCN), with the aim of managing, protecting, and restoring ecosystems degraded by human activities. These solutions generate simultaneous benefits for society and the environment, being an effective approach to address global issues, such as environmental degradation and the emission of Greenhouse Gases (GHGs). In addition, the application of NBS in urban areas offers advantages for biodiversity, productive sectors and the quality of life of vulnerable communities (FUNASA, 2015; TONETTI *et al.,* 2018; VIEIRA, 2020).

These technologies have gained prominence as viable solutions, capable of meeting the growing demands of sustainability in urban, industrial and agricultural areas. Among the examples of its application are the reuse of water in domestic and industrial environments, the conservation of green areas to increase soil permeability in cities and prevent flooding, in addition to the restoration of ecosystems to improve the urban microclimate. NBS are also effective in conserving biodiversity, reducing contact between humans and disease vectors (Fraga, 2020).

When it comes to sanitary sewage in disadvantaged areas, there is no single solution applicable in a standardized way. Each location requires a personalized approach that considers its environmental, social, human, and health particularities. The choice of solution must be adapted to these specificities, ensuring that local needs are met in a sustainable and efficient manner (VIEIRA *et al*, 2024d).

Proper sewage treatment is essential to mitigate negative impacts on health, the environment, and the social and economic development of a region, as sewage is a source of pollution. The correct disposal of human waste is essential for public health, as it prevents the spread of diseases such as cholera, typhoid fever and schistosomiasis. Improper disposal is directly related to several diseases, according to the Sanitation Manual

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of the National Health Foundation (FUNASA, 2015; NUVOLARI, 2021). Diseases associated with improper sewage disposal are mainly transmitted by direct contact with waste, where untreated sewage is discharged into open ditches or bodies of water. This contact, whether by ingestion or exposure of the skin, facilitates the spread of various diseases. In addition, the improper discharge of sewage into the soil can contaminate the water and result in diseases (FUNASA, 2015).

The accelerated urban growth in Brazil has resulted in a significant increase in the number of people living in precarious conditions, especially in favelas in the states of São Paulo and Rio de Janeiro. The absence of effective public policies and inclusive urban planning favors the rapid expansion of these areas, characterized by a lack of infrastructure and adequate sanitation (Maricato, 2015). This urbanization reflects the logic of capitalist accumulation, which expels the less favored classes to peripheral areas, resulting in an urban and housing crisis marked by precariousness (VILLAÇA, 2012).

The capitalist city tends to exclude the poorest, because private ownership of urban land requires an income that a large part of the population does not have. Many end up occupying public areas or idle land due to real estate speculation (VILLAÇA, 2011). When property rights are reinstated, residents are evicted, revealing the contradiction between economic marginalization and the capitalist organization of urban space. Landowners, in turn, play an important role in the unequal distribution of urban land, controlling its access (SINGER, 1980).

In the context of capitalist logic, access to housing in cities is directly related to the spatial contradictions generated by the social relations of production. These conflicts are reflected in land use and access to urban infrastructures (VILLAÇA, 2012). This scenario highlights socio-spatial inequalities, where favelas emerge as the materialization of the disparities generated by the capitalist urbanization process (HARVEY, 2005, 2020).

In light of this, there is an urgent need for viable solutions to sanitary sewage in favelas and urban communities. NBS offer a promising approach by integrating environmental conservation with improvements in sanitation infrastructure (FUNASA, 2015; TONETTI *et al.,* 2018; VIEIRA, 2020). In addition, these alternatives mitigate impacts on health and the environment, and promote social inclusion and sustainability in urban development (VIEIRA *et al.,* 2024c).

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METHOD

The methodology of this study uses a Dialectical Approach and the Indirect Documentation technique, based on IBGE data (2022) and a literature review. The Jardim Nova Esperança Favela, known as Banhado, located in São José dos Campos-SP, will be analyzed through a case study, with the objective of exploring the contradictions and conflicts in the unequal access to sanitary sewage services. The dialectical approach is particularly relevant to critically examine the contradictions, social and territorial dynamics that affect this vulnerable and marginalized community (MARCONI; LAKATOS, 2021).

RESULTS

NBS FOR SANITATION IN SLUMS AND URBAN COMMUNITIES

Faced with the challenges of sanitary sewage in favelas and urban communities, this study presents Nature-Based Solutions (NBS) as viable alternatives, respecting local particularities, promoting social inclusion and environmental conservation. The analysis considers factors such as the area needed, type of household system, type of sewage treated, and sludge removal. Below, 16 alternatives based on Funasa (2015), Tonetti et al. (2018) and Vieira (2020) are described, with emphasis on their characteristics and feasibility of implementation:

1) Vermifilter: a single-family or semi-collective sewage system that treats domestic sewage, including bleach and ash, and uses two main parts: an upper layer with sawdust, humus and earthworms, which perform the initial decomposition of organic matter, and a lower layer with filtering materials, such as stones. The system produces humus, which can be used as fertilizer, and needs periodic maintenance. With an area of 2 to 4 m², the vermifilter can treat between 400 and 1000 liters of sewage per day, making it ideal for small homes.
2) Biodigester Septic Tank: a single-family system developed by Embrapa (2001) to treat sewage from toilets, transforming it into biofertilizer. It consists of three connected 1000-liter water tanks, where the degradation of organic material occurs. The biofertilizer generated can be used on fruit trees, but not on vegetables that grow close to the ground. This system requires an area of 10 to 12 m² and does not treat greywater. The process can be improved with the addition of cattle manure to activate the microorganisms responsible for decomposition.

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3) Banana Circle: single-family system of complementary treatment for sewage or gray water. The effluent is directed to a circular ditch filled with branches and gravel at the bottom, where banana trees, papaya trees and other plants that absorb water and nutrients are planted. Microorganisms in the soil degrade organic remains. This method is effective in complementing the treatment of effluents from septic tanks, but should be avoided in areas with sandy soil or near groundwater and springs.
4) Fossa Verde: also called Evapotranspiration Basin (BET), it is a single-family sanitary sewage treatment system. The system uses the evapotranspiration of the plants to eliminate the effluent, and is composed of a central chamber for sedimentation and digestion of sewage, a filtering layer of materials such as gravel and sand, and a planting area for banana trees and other plants. The central chamber is waterproofed and equipped with pipes for inspection, being an ecological and low-maintenance solution, which takes advantage of the nutrients in the sewage for plant growth.
5) Filtration Ditch or Sand Filter: single-family or semi-collective sewage systems used for the treatment of pre-treated sewage, usually after the septic tank. Sewage is filtered through a top layer of sand and other layers of materials, such as gravel and pebbles. The microorganisms present in these materials help to decompose organic matter. With depths between 1.20 m and 1.50 m, these ditches are standardized by NBR 11799/90 and NBR 13969/97, and treated sewage must follow environmental legislation for its final disposal.
6) Constructed Flooded Systems (SAC): used to treat pre-treated sewage and greywater in single-family or semi-collective configurations. The system consists of waterproofed ditches, where the sewage is flooded. Aquatic plants, called macrophytes, act in the removal of pollutants, while microorganisms degrade organic matter. With a depth of up to 1 m, the SAC is dimensioned at about 2 m² per inhabitant. It is necessary to carry out plant maintenance, with periodic pruning, to maintain the efficiency of the system, which must follow environmental standards.
7) Compact Upflow Anaerobic Reactor (RAFA): a single-family or semi-collective system used to treat domestic sewage, especially from toilet water. Sewage enters from the bottom and rises through the reactor, where microorganisms break down organic matter anaerobically. At the top, plates separate the liquid from the solids and biogas. The system is standardized by NBR 12209/2011 and requires an area of

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1.5 to 4 m². Annual maintenance involves internal cleaning and proper ventilation of the pipes.

8) Biodigester: single-family or semi-collective sewage system that treats domestic sewage through the anaerobic digestion of organic matter. It has a closed chamber where decomposition occurs and a gasholder to store the biogas generated, which can be used as cooking gas. With an area of 5 m², the biodigester requires sludge removal every 2 to 4 years. In addition to treating sewage efficiently, this system promotes sustainability by generating clean energy and reducing environmental impacts.
9) Compartmentalized Anaerobic Reactor (RAC): single-family or semi-collective sewage system, used for the treatment of sanitary or domestic sewage. Different from a conventional septic tank, the RAC is divided into several chambers in series, which increases the efficiency of the treatment. It can be built with waterproof materials such as concrete rings, masonry, or plastic drums. Sludge removal should be carried out periodically, as needed, to keep the system efficient.
10) Infiltration Trench: single-family domestic sewage system used for complementary sewage treatment, which allows the effluent, after passing through a septic tank, to be absorbed by the soil. Infiltration facilitates the mineralization of sewage, preventing contamination of groundwater and surface water. The trenches are excavated with a depth of 0.60 m to 1.00 m and a width of 0.50 m to 1.00 m, and are used to disperse the effluent safely. The system is ideal for soils that allow good percolation.
11) Integrated Biosystem (BSI): single-family or semi-collective system that treats domestic sewage following ecological principles, with complete use of the waste in a treatment cycle. The process begins with a biodigester, which treats the sewage by anaerobic digestion and generates biogas, used as fuel. The sludge accumulated in the biodigester and in the anaerobic filter must be removed periodically. This system treats sewage efficiently and promotes sustainable waste management, in line with the principles of sustainability and energy reuse.
12) Cessa Seca: human waste treatment unit that does not require water for discharge, ideal for areas with water scarcity. It is a hole dug in the ground, over which a small house is built, with an average depth of 2.5 m. A vent pipe is installed to prevent the accumulation of gases, and it is recommended to cover the waste with lime, earth or

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ash to prevent bad smell. Construction should be done away from wells and areas subject to flooding, to avoid contamination.

13) Fermentation Tank: single-family or semi-collective sewage system for the treatment of feces and urine, composed of two independent chambers. One chamber is used until it is filled, at which point it is isolated for the mineralization of the material, while the second chamber comes into use. After fermentation, the mineralized material can be removed, allowing for continuous reuse of the chambers. This system is efficient, sustainable and ideal for regions with water scarcity or without conventional sewage systems.
14) Septic Tank: a simple and continuous sewage system used to treat domestic sewage in homes or small buildings. It works by separating solids and liquids. Solids settle to the bottom, forming sludge, while oils and fats float on the surface. The treatment is anaerobic, taking place in a waterproofed chamber, with a minimum depth of 1.5 m. The sewage is retained for 12 to 24 hours, allowing sedimentation and degradation of organic matter. Accumulated sludge and scum should be removed periodically.
15) Compostable Dry Toilet: a sewage system that treats feces and, occasionally, urine without the use of water. The waste is collected in a waterproofed chamber and, at each use, sawdust is added to start the composting process. It can be installed in an outdoor house or inside a residence, with the chamber made of masonry or plastic containers. When the chamber fills, the container is changed, facilitating safe treatment and the production of organic compost.
16) Anaerobic Filter: single-family or semi-collective sewage system, used to treat pre-treated domestic sewage. It consists of a chamber filled with filtering material, where microorganisms degrade the dissolved organic matter. Ideally, the filter is preceded by a septic tank, biodigester or anaerobic reactor, to maximize its efficiency. Constructed with concrete or masonry rings, the anaerobic filter requires periodic maintenance for sludge removal. It is effective in reducing the organic load of sewage, improving the quality of the final effluent.

SÃO JOSÉ DOS CAMPOS: A SMART CITY AND ITS FAVELAS

The municipality of São José dos Campos is located in the eastern region of the state of São Paulo, being one of the 645 municipalities in the state. With a population of 697,428 inhabitants (IBGE, 2022), the city's development was strongly influenced by its

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strategic geographic position and investments in infrastructure, which have boosted its economic progress over the years (VIEIRA *et al.,* 2024d).

São José dos Campos has a high Municipal Human Development Index (MHDI) of 0.807, being considered one of the best cities in Brazil and regional capital of the Metropolitan Region of Vale do Paraíba and North Coast (VIEIRA, 2023). The city was recognized as the first Smart City in Brazil by ABNT (SÃO JOSÉ DOS CAMPOS, 2022). This reputation was built through an urban marketing strategy that promotes the city as technological and smart (FORTI, 2021).

Paradoxically, according to Reschilian et al. (2020), between 2013 and 2016, São José dos Campos was home to about 112 favelas and urban communities, with approximately 70,000 people living in precarious conditions. The city still faces deep socio-spatial inequalities. Although there are more favored areas that stand out, there are less privileged regions, such as the Jardim Nova Esperança Favela, known as the Banhado, which remains marginalized (SILVA, 2020). Even located in the urban center, this community has lived for more than a century with precarious sanitation, exposing persistent territorial disparities, even in the midst of the city's technological development (Fig. 1).

FIGURE 1- SOCIO-SPATIAL CONTRAST IN THE JARDIM NOVA ESPERANÇA FAVELA

Source: collection of photojournalist Lucas Lacaz Ruiz (2024).

While the municipal administration seeks to promote São José dos Campos as a city of high efficiency and quality of life, there are concerns regarding this strategy based on a neoliberal capitalist logic, which privileges profit and competitiveness, selecting certain locations for investments to the detriment of the city as a whole and especially of the most vulnerable areas, such as the favela in focus here (FORTI, 2021). Such a smart city model

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tends to marginalize vulnerable groups, by prioritizing economic development rather than the full exercise of citizens' rights. Instead of reducing inequalities, this strategy seems to reinforce social exclusion and segregation, widening socioeconomic disparities (SOUZA, 2021).

The Jardim Nova Esperança Favela, one of the oldest in São José dos Campos, has an irregular occupation that has lasted for almost a century and is marked by low population density. Their houses are mostly single-storey and devoid of finishing, with improvised fences made of wood and other materials. The community is home to about 297 families, many of whom depend on local activities for subsistence, although most work in the commerce and services sector, benefiting from the proximity to the urban center (SILVA, 2020). Figure 2 illustrates the precariousness of the buildings and the absence of adequate infrastructure, with open sewage.

FIGURE 2 - HOUSING CONDITIONS IN THE JARDIM NOVA ESPERANÇA FAVELA

Source: collection of photojournalist Lucas Lacaz Ruiz (2024).

The idea is propagated that the presence of the Jardim Nova Esperança favela discourages tourism and negatively affects local commerce. These social representations contribute to social exclusion and aggravate the psychic suffering of residents, who live under the constant threat of displacement and housing insecurity (VIEIRA *et al.,* 2024e). The Municipality of São José dos Campos has promoted resettlement initiatives, and,

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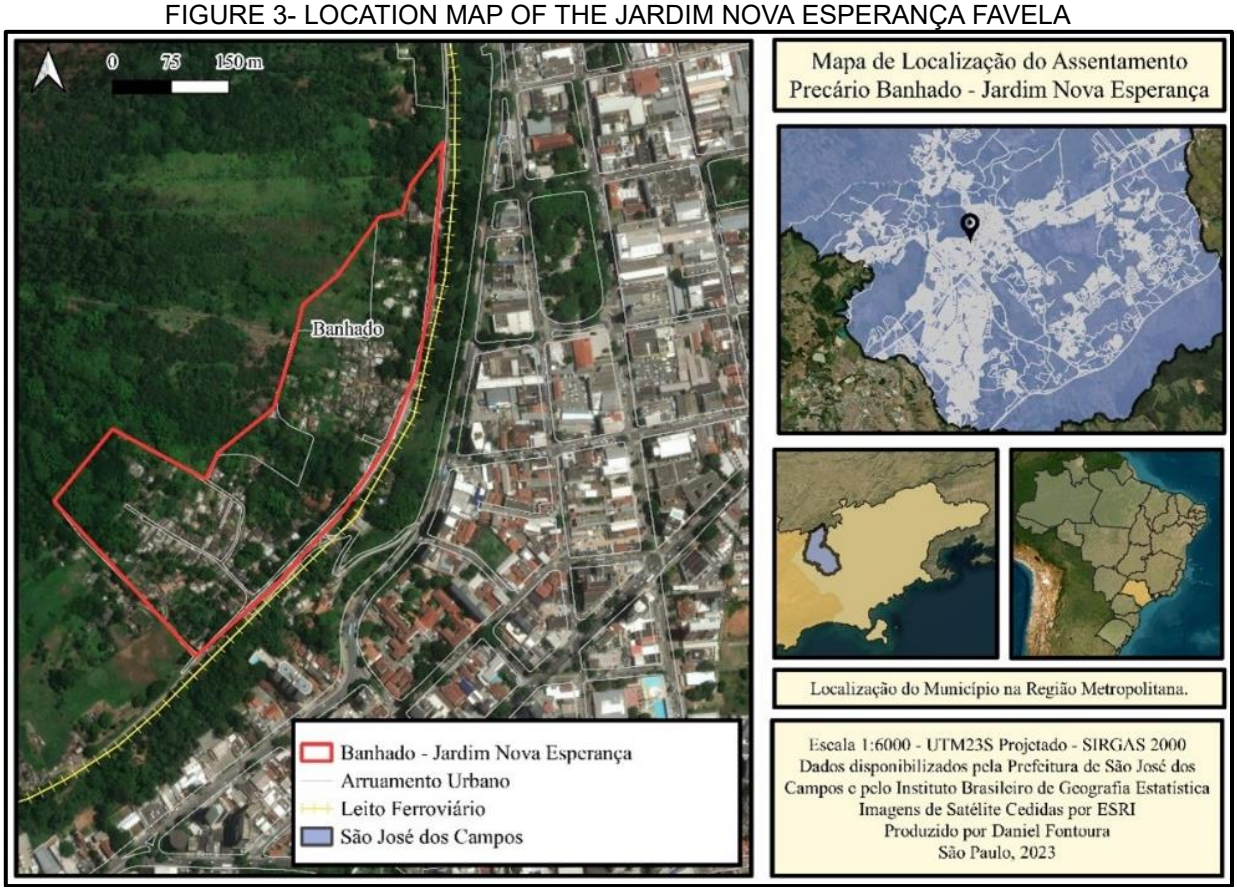
according to data from 2014, the number of families fell from 460 to 297 after some joined the Resettlement Program (SILVA, 2020).

Commercial establishments in the Jardim Nova Esperança favela, such as bars, markets and workshops, operate informally, often close to the owners' homes. The community also has religious temples, a community center and a sports court, which, in precarious conditions, serves as the only leisure space. The favela's privileged location, close to the urban center, arouses the interest of the real estate sector, as shown in Figure 3, which highlights the area's attractive potential, despite its deficient infrastructure conditions (VIEIRA, 2023). Here, we can see the proximity to the urban center and the spatial segregation in relation to the urbanized areas.

FIGURE 3- LOCATION MAP OF THE JARDIM NOVA ESPERANÇA FAVELA



Fonte: Vieira et al. (2024).

The possibilities of regularization of the Jardim Nova Esperança Favela were analyzed in detail in a technical report with the collaboration of the University of São Paulo (USP) and the Center for Studies in Rights and Inequalities (CEDD). The Plan considered the position of the Public Defender's Office of the State of São Paulo, which supported the

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community's permanence in its current location. The opinion defended solutions that balance environmental preservation with the fundamental right to housing (TAVARES; FANTIN, 2019).

The precarious conditions of the sanitary sewage services in Jardim Nova Esperança, evidenced in Figure 4, reveal a stark contrast with the image of São José dos Campos. This situation contributes to a scenario of socio-spatial vulnerability, amplifying disparities in access to basic rights and reinforcing the negative psychosocial effects associated with exclusion (VIEIRA *et al.,* 2024f).

FIGURE 4 - OPEN SEWAGE IN THE JARDIM NOVA ESPERANÇA FAVELA

Source: collection of photojournalist Lucas Lacaz Ruiz (2024).

The possibility of implementing NBS in the Jardim Nova Esperança Favela offers a promising approach by utilizing local resources and reducing dependence on large infrastructures. Although they do not solve the problem of the community as a whole, these decentralized solutions, in addition to addressing the challenges of sanitation, can strengthen community resilience, creating a healthier and more sustainable environment (VILLANOVA, 2022). The application of techniques that adapt to the local context can contribute to the improvement of sanitation in the community, promoting social and environmental development in a more balanced and inclusive way.

In addition, as many residences in this Favela occupy larger areas, as we can see in Figures 5, the implementation of NBS for sanitary sewage becomes a viable possibility,

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since there is space available. With the proper customizations, these alternatives have the potential to improve local sanitation, generating positive impacts on both public health and environmental preservation (VIEIRA *et al.,* 2024g).

FIGURE 5- HOUSING CONDITIONS AND OCCUPIED AREAS IN THE JARDIM NOVA ESPERANÇA FAVELA

Source: collection of photojournalist Lucas Lacaz Ruiz (2024).

DISCUSSION

Nature-Based Solutions (NBS) have proven to be sustainable and efficient in addressing sanitation challenges in slums and urban communities, as they minimize pollution of soil and water bodies, and can contribute to environmental conservation and generate positive social impacts, such as the creation of local jobs, promotion of public health, and social inclusion. These alternatives are aligned with the sustainable development goals, responding to the urgency of reducing inequalities in access to basic sanitation services (FUNASA, 2015; TONETTI *et al.,* 2018; VIEIRA, 2020).

With regard to financial and technical advantages, it is essential to consider the associated responsibilities, functionalities and technical guarantees (VIEIRA *et al.,* 2023). Some advantages of individual and decentralized domestic sewage treatment systems include:

1) reduced cost, due to simple operability and compliance with current market standards;
2) offer of products, tools and materials, with several alternatives, which reduces expenses related to resources and labor;
3) reduced energy consumption, accompanied by low maintenance costs, with no charges for treatment and other procedures;

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4) certain systems generate by-products that have the potential for reuse, such as fertilizers and items that can be used in different contexts and that can be used in engineering projects;
5) avoids the need to build a conventional sewage system, which may be unfeasible due to the requirement of substantial investments and the use of high-cost techniques;
6) It does not require the hiring of highly specialized workers.

The human, social and environmental advantages of individual and decentralized sewage treatment solutions represent an important qualitative differential. Funasa (2015), Tonetti et al. (2018) and Vieira (2020) present the following advantages and most relevant processes:

1) job creation and income opportunities by recruiting local workers, which generates an impact on the economy and social fabric, providing direct and indirect, short- and long-term jobs;
2) organic emergence of needs, jobs and occupations, which result from the expansion of the project and the creativity and actions of the people involved directly or indirectly. This covers the intellectual processes of planning, implementation, operation and maintenance until the identification and fulfillment of new requirements that may arise;
3) contribution to the substantial improvement of health and quality of life, which triggers positive impacts on the conservation of the environment and emphasis on valuing life and collective well-being;
4) good reception of this system by the community, due to its conformity with local habits and culture, as the cultural and ecological elements are considered;
5) low energy consumption, as softer and renewable technologies have less impact on the ecosystem and have the ability to be efficient for a longer period;
6) reduction in soil and water body pollution, which impacts the health, well-being and quality of life of communities.

The flexibility of NBS allows them to be adapted to the specific needs of each location, making them versatile tools for promoting social inclusion. With their ability to reduce costs and integrate into the cultural and ecological contexts of communities, these

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decentralized solutions become viable to address infrastructure disparities. In this way, NBS play an important role in advancing sustainability goals and reducing socio-spatial inequalities in vulnerable regions (VIEIRA *et al*., 2024c).

CONCLUSION

In this study, we address the issue of basic sanitation with an emphasis on sanitary sewage in favelas and urban communities, highlighting the case of the Jardim Nova Esperança Favela. The objective was to investigate the feasibility of Nature-Based Solutions (NBS) as sustainable alternatives to address the disparities caused by the lack of basic sanitation. The results indicated that NBS can be effective, promoting social inclusion, environmental conservation, and improved public health. These decentralized solutions demonstrate the potential to reduce costs, generate local jobs, and adapt to environmental and cultural conditions, contributing to sustainable development.

Regarding the limitations, we point out the need for broader evaluations on the application of NBS in different contexts and scales, in addition to the collection of specific data on the efficiency of each solution in varied scenarios. We suggest that future studies explore the long-term impact of these solutions, especially their replicability in other vulnerable communities.

The feasibility of the application of NBS in the Jardim Nova Esperança Favela is especially facilitated by the configuration of the residences, many of them located on lots with green spaces. Thus, these solutions can be customized to meet the needs of the community, providing improvements in local sanitation, in addition to generating positive impacts on public health and environmental preservation, reinforcing the commitment to sustainability and social inclusion.

This study contributes to the debate on sustainable sanitation by highlighting the importance of decentralized solutions adapted to the particularities of each community. By integrating local realities, these alternatives can promote a more inclusive social transformation, respecting the cultural and ecological aspects of each territory. In addition, these solutions facilitate the active participation of populations, promoting both environmental sustainability and social equity. This strengthens the notion of socio-environmental justice, where sustainable urban development aligns with the reduction of socio-spatial inequalities.

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