TOWARDS EMERGING SMART GREEN GOVERNANCE FRAMEWORK

RUMO A UM MODELO EMERGENTE DE GOVERNANÇA VERDE INTELIGENTE

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RESUMO

Este estudo investiga a Governança Verde Inteligente (Smart Green Governance), com foco na integração de sensoriamento remoto, plataformas móveis e outras tecnologias emergentes na gestão de florestas urbanas. Utilizando como estudo de caso São José dos Campos, uma cidade brasileira de médio porte conhecida por suas iniciativas de cidade inteligente, a pesquisa analisa como inovações como o projeto Arboriza São José utilizam ferramentas digitais, como QR codes e aplicativos móveis, para engajar os cidadãos na arborização urbana. Embora tecnologias como o monitoramento via satélite tenham aprimorado a gestão ambiental, o estudo destaca o aspecto participativo ainda pouco desenvolvido, o que limita o envolvimento da população. Argumenta-se que um modelo mais inclusivo de Governança Verde Inteligente, alinhado à teoria da Orientação para o Serviço Público (Public Service Orientation), promoveria a sustentabilidade ao fortalecer a colaboração entre cidadãos e governo. Os resultados oferecem subsídios para que governos locais equilibrem o avanço tecnológico com a participação comunitária na construção de ecossistemas urbanos sustentáveis e no enfrentamento de desafios ambientais, como a crise dos incêndios no Brasil em 2024.

Palavras-chave: Sensoriamento remoto; Florestas urbanas e periurbanas; Governança Verde Inteligente.

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ABSTRACT

This study investigates Smart Green Governance, focusing on integrating remote sensing, mobile platforms, and other emerging technologies in urban forest management. Using São José dos Campos, a medium-sized Brazilian city known for its smart city initiatives, as a case study, the research examines how innovations like the Arboriza São José project utilize digital tools such as QR codes and mobile apps to engage citizens in urban forestry. While technologies like satellite monitoring have improved environmental management, the study highlights the underdeveloped participatory aspect, limiting citizen involvement. It argues that a more inclusive Smart Green Governance model, aligned with Public Service Orientation theory, would enhance sustainability by fostering stronger collaboration between citizens and government. The findings offer insights for local governments on balancing technological advancement with community participation to create sustainable urban ecosystems and address environmental challenges, such as Brazil's 2024 fire crisis.

Keywords: Remote sensing; Urban and peri-urban forests; Smart Green Governance.

1 INTRODUCTION

Urban and peri-urban forests, although often overlooked, are increasingly recognized for their essential role in enhancing urban life quality. These green infrastructures provide critical environmental services, such as pollution absorption, flood risk management, and improved water quality, all of which contribute to mitigating the urban heat island effect (Breen et al., 2020). However, urban forestry is underutilized within smart city frameworks, where the focus remains on technological advancements in areas like transportation and energy. Incorporating urban forests into smart city development presents an untapped opportunity to enhance sustainability and enrich urban environments.

These urban "green lungs" are vital for sustainable urban planning. They absorb carbon dioxide, release oxygen, support biodiversity by providing habitats for wildlife, and promote the physical and mental well-being of residents by offering natural recreational spaces. Yet, even in smart city planning, urban forestry and green infrastructure often take a backseat to Information and Communication Technology and the Internet of Things (Albino et al., 2015).

In 2024, Brazil faces an environmental crisis with 205,815 fire outbreaks - 144% more than in 2023 - devastating ecosystems and impacting over 11 million people. This crisis highlights the urgent need for robust environmental governance that not only addresses immediate crises but also develops long-term strategies for ecosystem resilience. Despite growing global interest in green infrastructure, interdisciplinary research on urban forest governance remains limited (Žlender, 2021). As cities increasingly embrace digitalization, new possibilities for managing forests through real-time monitoring, automation, and augmentation emerge (Gabrys, 2022; Nitoslawski et al., 2019).

Digital technologies, such as IoT platforms and sensors, could revolutionize urban forest governance by enabling real-time tracking of deforestation, disease outbreaks, and structural changes in forests. However, fully realizing this potential requires bridging the gap between technological advancements and governance frameworks, necessitating deeper interdisciplinary engagement (Gabrys, 2022). The fusion of technology and environmental management forms the basis of Smart Green Governance—a framework that integrates forest policy with cutting-edge digital tools to create more responsive, efficient, and sustainable urban ecosystems.

To better align this framework with public service objectives, Smart Green Governance can be viewed through the lens of Public Service Orientation Theory, which emphasizes aligning public services with citizen needs and fostering collaborative relationships between governments and the public (Danielsson & Westrup, 2024; Gil-Garcia et al., 2020). By integrating technologies in urban forestry management, cities can enhance ecological stewardship and improve public services that meet demands for sustainability. Public service orientation supports the idea that modern governance should prioritize citizen engagement and transparency, both of which are central to Smart Green Governance.

This study explores how emerging technologies, such as remote sensing and IoT, can be utilized for urban forest governance within the Smart Green Governance framework. It focuses on how these technologies facilitate territorial monitoring, regulatory compliance, and community involvement, demonstrating their transformative potential for urban forestry (Gil-Garcia et al., 2023). The key challenge is integrating green infrastructure within smart city frameworks to enhance technological advancement, sustainability, and quality of life. Utilizing technology to monitor and manage these spaces is crucial for creating more resilient, environmentally sustainable urban environments (Howard-Grenville, 2021; Cooke, 2020).

Using São José dos Campos as a case study, this research contributes to the discourse on public service delivery, urban ecosystem management, and smart city integration. The study is structured as follows: first, we examine the concept of 'smart' within the context of smart cities and its relationship with green governance. Next, we outline the core components of Smart Green Governance and its alignment with Public Service Orientation Theory. We then present the case study methodology and findings, concluding with reflections on the broader implications of integrating urban forestry with smart city technologies and public service goals.

2 EMERGING TECHNOLOGIES AND GREEN GOVERNANCE IN SMART CITIES

The core aim of Smart Green Governance is to bridge the gap between the "smart" and "sustainability" dimensions of urban governance. Historically, smart city literature often separated these concepts, leading to criticism of the smart city paradigm for neglecting sustainability (Yigitcanlar & Kamruzzaman, 2018; Grossi & Pianezzi, 2017). However, recent shifts in the field have introduced more integrated concepts, such as Smart Urban Sustainability (Bibri & Krogstie, 2017), Smart Forests (Gabrys, 2020), Smart Urban Forestry (Nitoslawski et al., 2019), and the fusion of technology and ecology through Technoecology (Allan et al., 2018). This interdisciplinary collaboration is crucial for optimizing the environmental benefits of urban design and

governance. By clarifying these concepts, it becomes possible to understand the true scope of Smart Green Governance.

2.1 Evolution of the Smart Concept for Cities

The concept of smart cities has evolved significantly since Logan and Molotch's early vision of cities as efficient and adaptable to global markets (Logan & Molotch, 1987/2007). Initially, the "digital city" described how Information and Communication Technologies integrated with urban systems (Streitz, 2019; Anthopoulos & Fitsilis, 2010). This evolved into the "smart city" concept, focusing on technological advancements in urban management (Dameri, 2013). Over time, the idea of "green and sustainable cities" emerged, merging environmental and urban planning goals (Franchina et al., 2021), while the "information city" reflected growing internet-based public information dissemination (Lee et al., 2014).

Smart cities are now seen as multidimensional, using intelligent systems to enhance city functionality and involve communities in governance (Milkintas & Tamošiūnas, 2023). They leverage knowledge and technology to improve urban design and the built environment. ICT plays a central role in enhancing local governance, often referred to as the "Smart City" model (Klarić, 2022). However, critiques warn against over-reliance on technology, advocating for more citizen-centered strategies (Ahmad et al., 2022).

The term "smart" has varied interpretations, generally referring to advanced technologies like automation and data analysis (Gregory et al., 2023). Scholars have sought to define metrics for evaluating city "smartness," focusing on aspects like data accessibility (McKinsey Global Institute, 2018). Despite broad usage, a standardized definition remains elusive, reflecting the complexity and adaptability of the concept across different fields (Zhu & Hu, 2021; Singh & Miah, 2020).

2.2 Foundations of Green Governance

Green Governance has emerged as a critical framework for harmonizing environmental stewardship with sustainable development, particularly in urban and peri-urban areas. Forests are essential for maintaining ecological balance, making Green Governance especially relevant in urban contexts (Cooke, 2020). The development of Green Governance arose from the need to integrate environmental concerns into policymaking (Green et al., 2016), promoting sustainability, ecological stewardship, and inclusive decision-making.

At its core, Green Governance involves a wide range of practices aimed at resource management, pollution control, and conservation (Jones & Evans, 2006). In urban and peri-urban forestry, this governance model focuses on preserving these spaces as essential components of urban ecosystems (Young, 2010). The movement toward Green Governance reflects broader societal recognition of the value of natural resources and the necessity of their sustainable management (Oliveira et al., 2013).

A key concept within Green Governance is green infrastructure, which includes forests, parks, green roofs, and water bodies that contribute to biodiversity, climate regulation, and pollution mitigation (Finewood, 2016). However, urban and peri-urban forests face numerous challenges, including urban sprawl, pollution, and climate change (Miller, Hauer & Werner, 2015). These issues call for innovative management strategies that reconcile ecological integrity with urban development (Cariñanos et al., 2018).

Sustainable management of urban forests is essential not only for conserving biodiversity but also for improving residents' quality of life. Forests act as natural climate regulators and recreational areas, playing a pivotal role in urban sustainability. Protecting and enhancing these forests through sustainable practices ensures the resilience of ecosystem services (Howard-Grenville, 2021; Cooke, 2020).

2.3 Integration of Smart Technologies in Green Governance

Smart Green Governance is a transformative, people-centered approach that transcends traditional smart city and green governance paradigms. It emphasizes sustainable development through a strategic fusion of technology, ecological stewardship, and innovative governance. This approach entails comprehensive processes and structures implemented by public sector management to guide, monitor, and evaluate organizational activities while addressing existing power imbalances (Grossi & Welinder, 2024; Criado & Gil-Garcia, 2019; Gil-Garcia, Dawes & Pardo, 2018).

The application of digital technologies in urban environmental management has become essential, particularly during global challenges like pandemics. Technologies such as Geographic Information Systems (GIS), remote sensing, and other digital tools enable urban planners and policymakers to monitor soil health, detect floods, assess air quality, and manage urban forests, safeguarding critical green infrastructures like forests and watersheds (Howard-Grenville, 2021; Seixas et al., 2020).

Smart Green Governance prioritizes the use of these advanced technologies to enhance environmental protection and sustainable resource management. This model fosters collaboration across stakeholders, promoting transparency, accountability, and active citizen engagement in monitoring biodiversity and ecosystem services (Criado & Gil-Garcia, 2019). Local governments play a central role, as they are responsible for creating governance systems that integrate data-driven planning and encourage citizen participation. Technology acts as both a tool and a platform, enabling communities to contribute to decision-making processes related to urban green spaces.

However, challenges such as financial limitations and political instability can hinder the development of effective environmental policies, including urban forestry programs. To overcome these, resilient governance practices must incorporate new data, encourage public involvement, and protect

green infrastructures from threats like pollution and climate change (Aquino & Lopes, 2017).

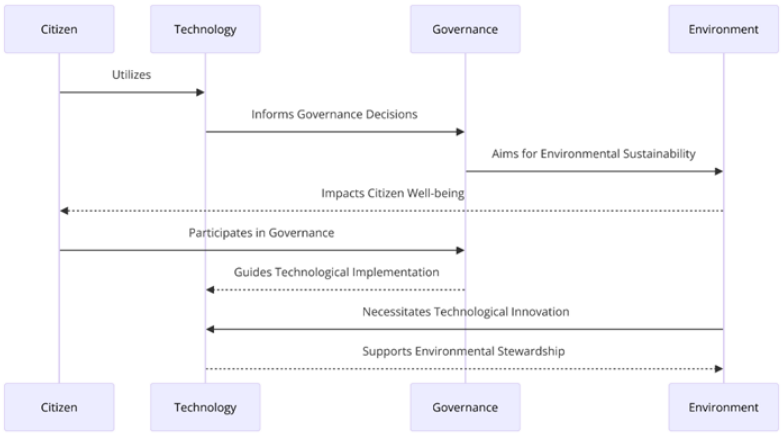
By integrating best practices from public governance paradigms—such as Network, Digital, and Collaborative Governance—Smart Green Governance aligns with modern strategies to tackle climate change. It employs cutting-edge technology to ensure environmental preservation, combining efficiency in public service with a comprehensive framework for sustainable urban development.

2.3 Interactions within the Smart Green Governance Model

The Smart Green Governance model presents a holistic approach to managing environmental issues, emphasizing the interconnectedness of citizens, technology, governance, and the environment (Figure 1). A dynamic, reciprocal relationship exists between these elements, fostering seamless integration that enhances sustainability and promotes ecological stewardship.

At the heart of this model is the active engagement of citizens with technology to promote sustainable practices. By utilizing applications that monitor green areas or participating in shared transportation systems, individuals contribute directly to environmental sustainability. This citizen-driven use of technology not only empowers personal responsibility but also generates valuable data that informs broader governance decisions.

FIGURE 1 Interactions within Smart Green Governance model



Source: authors

Technology, in turn, serves as a critical link between everyday practices and policymaking. Data harvested from technological applications provide insights crucial for informing governance. This information enables policymakers to assess the effectiveness of current environmental initiatives and adjust policies to reflect the real-time needs and behaviors of the population.

Governance, with its focus on creating and implementing policies that promote environmental sustainability, directs the development and application of green technologies. This stewardship ensures that technological advancements align with overarching goals of environmental conservation and sustainability. However, the environment itself applies pressure on governance systems to adapt and innovate. Challenges such as climate change and resource depletion demand new technological solutions, which governance frameworks must incorporate to remain effective. This ongoing need drives the continuous evolution of technology, aimed at addressing these environmental challenges.

As new technologies are developed and deployed, they have a direct and positive impact on the environment. From reducing emissions through

smarter energy grids to enhancing biodiversity and green infrastructures through improved land use practices, technology serves as an agent of environmental stewardship.

Finally, the state of the environment significantly influences citizen well-being. A well-maintained and sustainable environment not only supports the physical health of individuals but also improves their overall quality of life. This beneficial cycle reinforces the need for robust Smart Green Governance, in which each component—citizens, technology, governance, and the environment—is interconnected. This ensures that technological advancements and governance strategies evolve in response to both human and environmental needs.

Thus, the Smart Green Governance model exemplifies a comprehensive, integrated approach to managing environmental issues. It highlights the indispensable role of technology in achieving sustainable development and underscores the importance of an inclusive and collaborative governance framework in addressing the global environmental challenges of our time.

3 METHODOLOGY

In the context of Smart Green Governance, the integration of technologies like remote sensing is crucial for urban forest monitoring. This study focuses on São José dos Campos, a medium-sized Brazilian city recognized for its innovative use of smart technologies to enhance urban forest management. The city serves as a model of how digital tools and platforms, particularly through the Arboriza São José project, foster citizen engagement and improve governance in urban environmental management.

São José dos Campos, situated in the Vale do Paraíba region near the Serra da Mantiqueira mountains, offers an ideal case study due to its environmental policies and technological innovations. As part of the Atlantic Forest biome, the city is one of the most biodiverse ecosystems in the world, benefiting from stringent conservation policies that promote sustainable land use. In

2023, the Brazilian Association of Technical Standards (ABNT) recognized São José dos Campos as Brazil's first smart city, highlighting its integration of technology into public services such as healthcare, education, urban mobility, and public safety.

A key element of the city's smart transformation is the Arboriza São José project, an urban greening initiative that uses a mobile platform to engage citizens in urban forest management. Through QR codes placed on trees, citizens can access data on species, height, and location, encouraging public participation in the city's green spaces. The focus on mobile technology is strategic, leveraging the widespread use of smartphones to facilitate real-time interaction between citizens and city officials. Residents can report issues like damaged trees or the need for replanting, promoting a collaborative approach to urban forest conservation.

The decision to focus on mobile technology reflects its ability to reach a broad audience, making it an accessible tool for public engagement. The Arboriza platform offers an example of how mobile applications can enhance public participation by making urban forestry information easily available. Additionally, São José dos Campos integrates remote sensing technologies through its GeoSanja platform, which provides satellite imagery and geospatial data to monitor environmental changes. This platform allows for transparency in urban planning and environmental management by enabling users to access layered maps and environmental data.

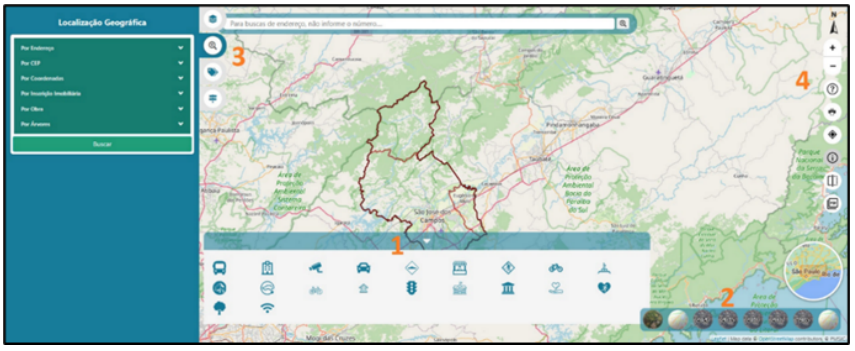
The city's combination of mobile and satellite technologies supports sustainable urban development by facilitating data-driven governance. These tools allow São José dos Campos to maintain its urban forests while promoting citizen involvement and environmental stewardship. The success of these initiatives has earned the city international recognition, such as the Tree Cities of the World award.

3.1 Data Collection Methods

This study employed a multi-faceted data collection approach to examine the integration of remote sensing and emerging technologies in São José dos Campos. From July to October 2023, we conducted in-depth interviews with local government officials, civil society members, and technology managers from companies like Visiona Tecnologia Espacial and GeoPixel, which contributed to the development of platforms like GeoSanja. These interviews were based on qualitative methods outlined by Wagner (2018) and informed by the role of leadership and trust in smart city collaborations (Chun et al., 2022).

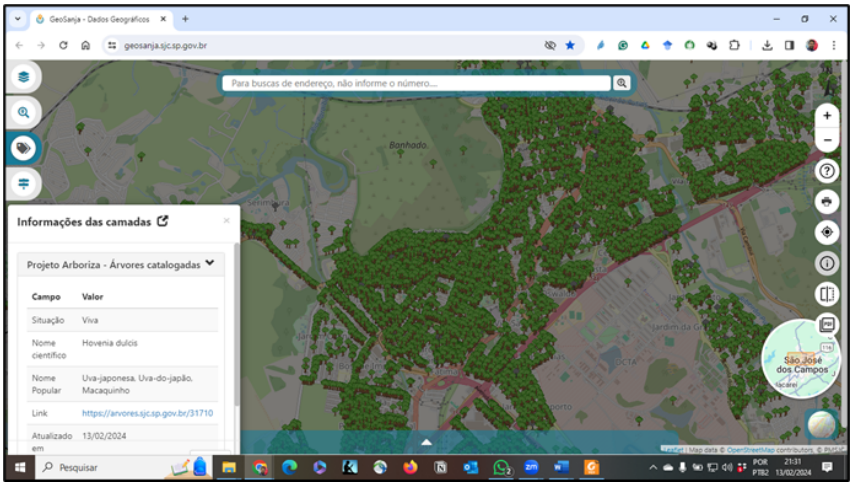
Additionally, we observed Municipal Environmental Council meetings to gain insights into real-time decision-making processes regarding urban forest management. This allowed us to understand how policies are shaped and implemented in the city. We also conducted a review of governance documents, including the city's ICT policies and environmental management plans, which contextualized the interview and observation findings within São José dos Campos' broader regulatory framework.

FIGURE 2 Geosanja platform



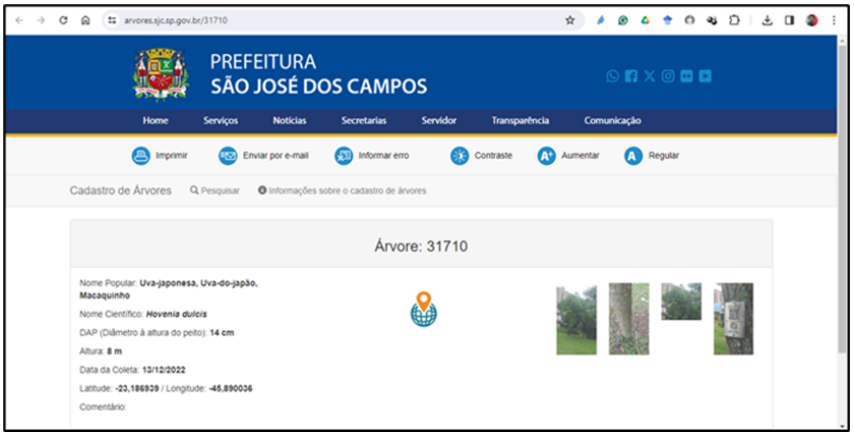
Source: Research data

FIGURE 3 GeoSanja platform - Arboriza program – Tree mapping



Source: Research data

FIGURE 4 Arboriza program



Source: research data

By triangulating interviews, observations, and document analysis, this study provides a comprehensive view of how São José dos Campos integrates smart technologies into its urban forest management. The city's use of platforms like Arboriza and GeoSanja illustrates the potential of digital tools to

enhance citizen engagement and promote sustainable urban development, contributing to the broader discourse on Smart Green Governance.

4 FINDINGS AND DISCUSSIONS: THE DYNAMICS TOWARDS EMERGING SMART GREEN GOVERNANCE

The study explores the evolution of Smart Green Governance and its impact on enhancing public value within the smart city framework. This approach marks a shift in urban governance paradigms by emphasizing both formal and informal relationships between government and citizens. In São José dos Campos, the administration adopts a managerial governance mode that positions the local government as a central actor, focusing on data-driven innovation and public value co-creation. The Arboriza São José program exemplifies this approach, where stakeholders, including public agencies and citizens, collaborate to promote participatory governance.

However, the integration of advanced digital technologies challenges existing governance structures, aiming to transform city management by centering decisions around data. This shift is crucial for enhancing urban environmental management but also raises concerns regarding the exclusion of ordinary citizens from the decision-making process. The study reveals two key aspects critical to Smart Green Governance in São José dos Campos: the Technology-Driven Aspect and the Participatory-Centric Aspect.

4.1 Technology-Driven Aspect

In the technology-driven scenario, the local government in São José dos Campos leverages advanced tools like satellite monitoring, heavily emphasizing the "smart" side of Smart Green Governance. The partnership with Visiona Tecnologia Espacial demonstrates how high-resolution satellite imagery supports environmental regulation and enforcement. This technology

provides real-time data on illegal land use, deforestation, and other environmental concerns, offering a crucial method for efficient and sustainable urban management.

The WebVis platform facilitates access to this data, ensuring that municipal authorities can promptly address environmental issues. This aligns with Gil-Garcia et al. (2020) and Lanza et al. (2016), who suggest that mobile government (mGov) represents a specific application of e-government, with governments worldwide investing significant resources in such initiatives. While mobile phones have not yet become the primary channel for mass public service delivery, as Gil-Garcia et al. (2020) argue, the satellite and mobile platforms used in São José dos Campos exemplify how digital tools can support more informed, data-driven urban governance.

However, mobile technologies in governance must be understood within broader contexts, including policy, management, and business ecosystems. The integration of mobile platforms into Smart Green Governance is a strategic endeavor requiring coordination among various stakeholders to establish long-term, sustainable projects. This data-centric approach has succeeded in improving the efficiency and accuracy of environmental monitoring but still lacks the depth of civic engagement that is necessary for participatory governance.

4.2 Participatory-Centric Aspect

The second aspect of Smart Green Governance focuses on the participatory element, where civic engagement is essential for co-creating public value. However, this dimension in São José dos Campos remains underdeveloped. Programs like Arboriza São José, designed to foster public involvement through technology, have largely been limited to one-way communication. For example, while citizens can use QR codes on trees to access information about urban flora, there is no channel for them to communicate back with the government regarding tree maintenance or issues.

This limitation undermines the program's potential to be a model for participatory governance. Without a two-way communication channel, citizens are effectively excluded from contributing feedback, a critical component of Public Service Orientation (PSO) theory. According to Danielsson and Westrup (2024), public value is co-created when citizens actively participate in decision-making processes. The absence of active citizen engagement in Arboriza São José reveals a gap between the goals of Smart Green Governance and its execution, emphasizing the need for improvements in how participatory governance is realized in practice.

Both aspects of Smart Green Governance—technology-driven and participatory—fall under the broader umbrella of urban environmental governance. However, they represent two distinct approaches to achieving environmental sustainability and efficient urban management. The first is heavily technology-centric, focusing on using advanced tools to improve service delivery, while the second attempts to foster a more collaborative approach but remains limited in its execution of genuine participatory governance.

The integration of remote sensing, mobile platforms, and satellite data collection in São José dos Campos has enhanced the ability of municipal authorities to monitor and manage green spaces. This aligns with the principles of e-government, where digital tools improve the efficiency of public services. However, as Gil-Garcia et al. (2020) suggest, governments must also invest in creating systems that allow citizens to actively engage in governance through mobile platforms. Improving the participatory aspect of Smart Green Governance would involve establishing two-way communication channels, ensuring that public input is integrated into policy and decision-making processes.

Mobile technologies must not only serve as tools for data collection but also as platforms for fostering public engagement. As Gil-Garcia et al. (2020)

point out, mobile government (mGov) can lead to more responsive, inclusive, and effective governance if properly implemented. This includes allowing citizens to contribute to environmental monitoring efforts by reporting issues and offering suggestions through mobile platforms.

Thus, to embody the principles of Smart Green Governance more effectively, São José dos Campos needs to enhance citizen engagement by creating more interactive and participatory digital platforms. This approach will help bridge the gap between technological innovation and the co-creation of public value, ensuring that urban governance is both data-driven and community-focused.

The findings reveal that while São José dos Campos has made significant strides in integrating technology into urban forest management, the participatory dimension of Smart Green Governance requires further development. Enhancing citizen involvement through mobile platforms and two-way communication channels will lead to more responsive, efficient, and sustainable outcomes for urban ecosystems. This aligns with the broader goals of public service orientation, where public value is co-created through collaborative governance and active civic participation. By improving the balance between technological tools and public engagement, São José dos Campos can become a model for Smart Green Governance, supporting both sustainability and effective urban management.

5 CONCLUSION

As environmental challenges intensify, particularly with Brazil's 2024 fire crisis, there is an urgent need for cities to adopt strategies like Smart Green Governance. This approach leverages data-driven technologies to monitor forest health, predict fire risks, and respond swiftly to environmental threats. São José dos Campos illustrates how Smart Green Governance can integrate technological innovation with environmental management, using tools like

satellite monitoring and the Arboriza São José program. However, the research reveals that without strong citizen participation, these technological advancements may not fully address public needs. Public service orientation emphasizes the importance of active citizen engagement in governance. To ensure Smart Green Governance is both effective and inclusive, two-way communication and citizen co-creation must be enhanced. Mobile platforms for environmental reporting could bridge the gap between technology and citizen involvement. Future research should explore the intersection of socio-economic diversity and technological infrastructure in various urban landscapes and investigate the potential of emerging technologies like AI and IoT in advancing governance models. Understanding Smart Green Governance's long-term effects on urban biodiversity and residents' quality of life will help inform policies promoting resilient and sustainable urban environments.

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