Ornamental Horticulture
ISSN 2447-536X | HTTPS://ORNAMENTALHORTICULTURE.EMNUVENS.COM.BR/RBHO
SBFPO Sociedade Brasileira de Floricultura e Plantas Ornamentais

Scientific Article

Trajectory of landscaping and multifunctionality around urban rivers: the case of Angers

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Abstract

Due to urban population growth, there is increasing pressure to utilize open spaces in urban centers, particularly in challenging areas like watercourses. However, traditional approaches such as canalization and drainage techniques have proven ineffective and unsustainable in the face of climate change challenges. This research aims to analyze the landscapes and multifunctionality of river environments in Angers, France, identifying their functions and historical evolution, considering the population contributions and the impact on quality of life. The research employed a geohistorical analysis to examine the social, economic, and environmental dimensions through the construction of a historical timeline depicting changes in the urban space influenced by the municipality's watercourses (Quantitative analysis). Additionally, key actors' actions were captured and discussed through interviews and questionnaires (Qualitative analysis). This comprehensive approach facilitated the analysis of the evolutionary process of urban rivers and the identification of their multifunctional use, contributing to urban sustainability. The implementation of green and blue infrastructures (GBIs) played a significant role in this process, and participatory interventions helped garner public support for reintegrating rivers into the urban landscape. The interviews highlighted that the successful implementation of multifunctional infrastructures relies not only on clear legislation but also on political will and the adoption of sustainable economic alternatives.
Keywords: garden history, green and blue infrastructures, sustainable cities, urban watercourses.

Resumo

Trajetória de paisagismo e multifuncionalidade em torno de rios urbanos: o caso de Angers

Devido ao crescimento populacional urbano, existe uma pressão crescente para utilizar espaços abertos em centros urbanos, especialmente em áreas desafiadoras como cursos d'água. No entanto, abordagens tradicionais, como canalização e técnicas de drenagem, têm se mostrado ineficazes e insustentáveis diante dos desafios das mudanças climáticas. Esta pesquisa tem como objetivo analisar as paisagens e a multifuncionalidade dos ambientes fluviais em Angers, na França, identificando suas funções e evolução histórica, considerando as contribuições da população e o impacto na qualidade de vida. A pesquisa utilizou uma análise geo-histórica para examinar as dimensões sociais, econômicas e ambientais por meio da construção de uma linha do tempo histórica que retrata as mudanças no espaço urbano influenciadas pelos cursos d'água do município (Análise quantitativa). Além disso, as ações dos principais atores foram capturadas e discutidas por meio de entrevistas e questionários (Análise qualitativa). Essa abordagem abrangente facilitou a análise do processo evolutivo dos rios urbanos e a identificação de seu uso multifuncional, contribuindo para a sustentabilidade urbana. A implementação de infraestruturas verdes e azuis (IVAs) desempenhou um papel significativo nesse processo, e intervenções participativas ajudaram a obter o apoio público para reintegrar os rios à paisagem urbana. As entrevistas destacaram que a implementação bem-sucedida de infraestruturas multifuncionais depende não apenas de legislação clara, mas também de vontade política e adoção de alternativas econômicas sustentáveis.
Palavras-chave: cidades sustentáveis, cursos d'água urbanos, história dos jardins, infraestruturas verdes e azuis.

Introduction

The rapid and disordered growth of cities, especially after the industrial period, has led to the effect of conurbation and to the suppression of vegetation and occupation of free spaces within urban perimeters as well as agricultural spaces on urban peripheries (Mok et al., 2014; Sousa et al., 2022). Many of these occupied spaces comprise the surroundings of rivers and their floodplains (Bonin, 2007; Sousa et al., 2022).

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https://doi.org/10.1590/2447-536X.v29i4.2659
Received June 7, 2023 | Accepted Oct 11, 2023 | Available online Oct 31, 2023

Editor: Joelmir Marques da Silva

Problems such as floods and changes in the spatial distribution of rainfall, river silting, air pollution, soils, rivers and surface and underground aquifers have become common, especially in industrial cities (Silva and Travassos, 2008). During the last decade, due to climate change, these problems have worsened, and others have occurred, such as heat islands, lack of water and energy, and impacts on transport systems due to flooding (IPCC, 2013; PBMC, 2016; Hoegh-Guldberg et al., 2019). Watercourses played a role in recreational events supporting structures such as fountains and public baths (Biquet, 2016) and facilitated agriculture through irrigation canals (Dermody, 2014). Thus, evaluating the actions of local governments to reduce these effects is essential for the development of more sustainable and resilient cities (Teixeira and Pessoa, 2020).

In this context, starting in the 1970s, international conferences (the Club of Rome, United Nations Conference on the Human Environment in Stockholm-Sweden, and Eco 92 in Rio de Janeiro-Brazil) established the concept of Sustainable Development in Agenda 21, which aims to improve the quality of life through ecological, ethical and participatory alternatives that are concerned with inherited cultural and natural values (Hoyuela-Jayo, 2017).

The member countries of the European Union (EU) have adopted the "Pan-European strategy for the protection of biological diversity and landscapes". This strategy aims to establish a European ecological network comprising core zones, ecological corridors, zones to be restored, and buffer zones. This initiative has led to the development of the "green and blue plot" (GBP) concept (Lamond and Everett, 2019; Sousa et al., 2022), which has been integrated into the legislation of various countries, including France, at different territorial levels (Clergeau, 2012; IAU, 2011; Oliveira and Costa, 2018).

In addition, there are diverse ecosystem services (ES) that are attributed to GBI, including health, leisure (including tourism activities) and entertainment, fostering a sense of belonging and community, besides risk prevention and biodiversity reserves (Cormier et al., 2010; Laugier, 2010; Raimundo and Sarti, 2016; Paiva et al., 2020; Drew-Smythe et al., 2023). There is a growing consensus that these services have a vital role in urban sustainability (Coutts and Hahn, 2015; Kim and Coseo, 2018).

Correlating ES and multifunctionality poses new challenges for future public policies, requiring a balance between ecological, social and economic functions (Hansen and Pauleit, 2014). Given the complexity of urban ecosystems, incorporating the concept of ES into decision-making processes can promote progress in biodiversity preservation within urban environments (McDonald, 2009).

GBIs facilitate the creation of multifunctional green spaces (Lotfi, 2017; Salgado et al., 2020; Garcia, 2021; Sousa et al., 2022; Luz et al., 2023), which are increasingly valued by public actors (Clergeau, 2012; Mehdi et al., 2012). Urban rivers and their surroundings present an opportunity to innovate city planning, restore ecology, and create valuable public spaces (Mondragón-Monroy and Honey-Rosés, 2016).

In this context, the objective of this study is to analyze the trajectory of the landscape transformations and multifunctionality of the surrounding rivers of the city of Angers (France) and the influence on the quality of life by identifying their functions and evolution. Geohistorical analysis is crucial when studying landscape and urban sustainability as it allows for the observation of transformations over time. Besides of this, the contributions of public actors and the view and feelings of the population were also analyzed. This analysis enables the evaluation of the present state and prediction of future directions, aiding in better management of urban territories with more sustainable practices. To achieve this, the use of questionnaires and semi-structured interviews with key stakeholders, managers, and users of urban rivers provides essential insights (Berque, 1994; Coy, 2013; Verbrugge, 2019; Sousa et al., 2022).

Material and Methods

Angers is the core city of the second largest metropolis in the Pays de la Loire region in France. Known as the plant pole of France (Pavie and Rivière, 2011), it has an area of 42.7 km², a population of 154,508 inhabitants, and a population density of 3,581 inhabitants km^{-2} according to the last census conducted by the National Institute of Statistics and Economic Studies in 2018 (INSEE, 2020). It has a Cfb oceanic climate according to the Köppen classification (Mballo et al., 2021). The hydrographic density is a striking feature of the territory; as one of the largest confluence zones of France within the set of low Angevine valleys (SCoT, 2016), it is classified as a wetland with international importance.

To assess the changes in land use and occupation along watercourses in the city of Angers, France, three analyses were performed: a) geohistorical analysis of the landscape using Patchwork Quilt methodology (Paiva et al., 2021), which was developed for studies of historical gardens and integrates analyses of different areas to construct the history and evolution of a space; b) quantitative analysis of land use and occupation around the rivers; and c) qualitative analysis via questionnaires and interviews (Figure 1).

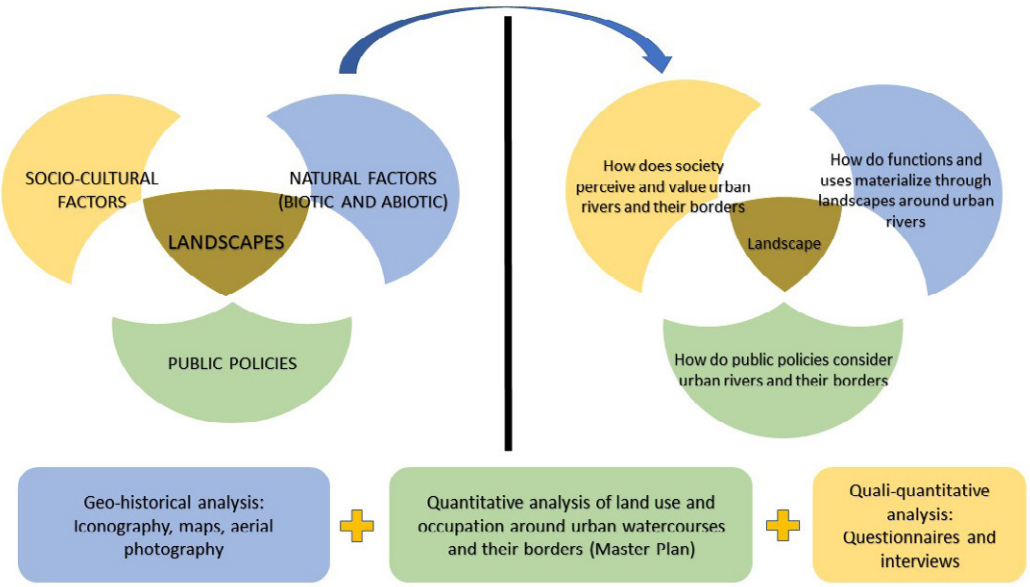


Figure 1. Methodological scheme, encompassing the analysis performed: Geohistorical (blue), quantitative (green), and quali-quatitative (yellow).

Quantitative analysis

A compilation of geohistorical information on the origin and formation of the city was performed encompassing the social, economic, and environmental dimensions by using bibliographies, iconographies, topographic maps from 1776 to 2016 and aerial photographs from 1958 to 2016. The aerial photographs were the most recent images publicly available for analysis on the website of the National Institute of Geographic and Forestry Information (IGN) and the Municipal Archives of the City of Angers. The maps and aerial photographs were georeferenced and analyzed using QGIS 3.6 software (QGIS, 2017) following the cartographic standardization proposed by Menezes and Fernandes (2016).

This analysis involved tracing a historical timeline of changes in the urban landscape influenced by the municipality's watercourses and identifying the current state of these areas using the most recent aerial image available (2016). Subsequently, the data were analyzed by observing the changes in the landscapes of watercourses at different times as well as their uses while considering the main transformations in the landscapes analyzing city maps from different periods. It was analyzed how natural, sociocultural, and economic processes and their interactions materialize in the landscapes of urban rivers and how public policies contribute to this.

This study examined the social, natural, and economic dimensions of river environments. The social dimension encompasses leisure, entertainment, and cultural aspects that contribute to overall well-being. The natural dimension focuses on preserving the natural habitats and biodiversity of riverbeds and banks. The economic dimension considers commercial activities, industries, and the value of land adjacent to rivers. These dimensions are interconnected, although in some cases, one or more dimensions may take precedence over others.

The areas surrounding the major river axes that cross the municipality were analyzed, as well as the small rivers that make up the city's drainage network, accounting for the flood zone that is included in the flood risk prevention plan (PPRI, 2017). The immediate surroundings of the small rivers were identified in the maps of a larger scale; some are not registered in the cartography of the watercourses of the Maine and Loire.

Watercourses that had a natural bed at their origin were considered, even when strongly anthropized (such as channeled watercourses) and therefore mischaracterized and lifeless (IG, 2015). Thus, a buffer of 100 m was made around the flood zone that encompasses the banks of the Maine River and Lake of Maine and 30 m for smaller water courses (up to 10 m wide).

Quantitative analysis of land use and occupation around urban rivers (PLUi)

The data on land use and occupation were obtained for analysis through the website (IGN) and were the most recent for 2016. These data were updated by manual vectorization in 2019 and then grouped into four categories: a) Impervious zones: built and/or paved areas with impermeable surfaces; b) Herbaceous vegetation and other permeable areas: herbaceous formations (lawns and pasture, arable land, rose bushes); ligneous formations such as vineyards and lianas (vines) and zones with mineral material (rock-earth, railways, trails, beds); c) Tree vegetation (wooded spaces): tree formations with a dominance of hardwoods or conifers of variable surfaces (from forest to forest). Shrub and subshrub formation; d) Water surface: surface occupied by rivers, lakes, dams, etc.

The percentage of each class within the study zone was calculated and the plant components present in the urban planning documents were identified (Table 1). The multifunctional uses around the rivers were highlighted based on the registration of green spaces by the Angers parks and gardens service.

Table 1. Plant components protected by the urban planning code and identified in the master plan

Plant Component	Definition
Heritage arboreal space	Woodland, forest or reforestation that correspond to landscape, social, ecological or heritage issues.
Tree presence recognized	Woodland, forest or space with a prevalence of tree species whose landscape role is recognized.
Landscape space to be preserved	Space open to the public, managed by the public agency, has leisure and entertainment infrastructure (public gardens, urban parks, squares, green spaces...)
Heritage gardens	Ornamental space characterized by a very structured composition plane.
"Heart island"	Set of private gardens with plant dominance, considered "breathing space" in the inhabited urban area.
Hedges, alleys, tree alignment	Linear elements that structure the landscape following waterways and path circuits, valuing and creating perspectives.
Landscape structural axes	Penetrating roads and boulevards that circulate throughout the city. They participate in the landscape reinforcement of the urban space.
Notable trees	Exceptional living trees in terms of their age, size, shape, past or even history.

Qualitative analysis: Questionnaires and interviews

Interviews were conducted to capture and discuss the actions of key actors in the territory, while questionnaires were used to gather the population's perception of these spaces regarding the urban watercourses in Angers.

Structured questionnaires

A questionnaire consisting of 22 direct and descriptive questions, in French language, was used in this study. The questionnaire covered socioeconomic characteristics (age, gender, income, and education), opinions on watercourses and their landscapes regarding quality and accessibility, evaluations of water presence in public green spaces, desired uses for these areas, and respondents' relationship with green spaces, vegetable gardens, and gardens.

A total of 433 participants from Angers and the metropolitan region voluntarily completed the questionnaire between October 2019 and July 2020, using the Google Forms platform. The respondents remained anonymous. Nonprobability sampling by accessibility was employed, where participants were selected based on convenience, volunteerism, or chance encounters (Aaker et al., 2001). The sampling method allowed for a 5% margin of error.

Descriptive statistics and frequency distribution were employed for data analysis (Martins and Theóphilo, 2009), and the collected data were compiled and analyzed using the R software (R CORE TEAM, 2016).

Semi-structured interviews

The use of semi-structured interviews allows the exploration of facts whose discourse is the main vector in regard to representation systems (constructed thoughts) and social practices (experienced facts) (Blanchet and Gotman 1992).

The interviews were conducted with different local actors, e.g., representatives of a civil society, such as the Association of the Bird Protection League (LPO) (Representative 1), and of the private sector, such as the Association of Commerce and Industry (CCI) (Representative 2), of the public sector, such as the Director of Parks and Gardens of Angers (Representative 3) and the Vice-President of Ecological Transition and Displacement (Representative 4). Semi-structured interviews were conducted with key actors, and the survey questions were adapted based on each interviewee's profile and role. The objective was to gather their perspectives on green and blue infrastructures (GBIs), their primary components, and the challenges they faced during implementation. The clarity of legislation on this topic and efforts made to address any issues were also explored.

All interviews were recorded with the participants' consent, and relevant excerpts containing their responses to the questions were transcribed for further analysis and discussion.

Results and Discussion

Angers, origin and the situation of the rivers before the French Revolution

The city is mostly cut by the Maine River and its tributaries, which flow into the Loire River in the south of the territory, crossing the urban area of the city. Within the urban zone, on its right bank, the Maine River has tributaries with preserved natural landscapes; on the left bank, there is a denser drainage network, which remains largely buried.

The city of Angers in France was established at the confluence of the Mayenne, Sarthe, Loir and Loire Rivers, in the presence of a rock formation strategically positioned along the course of the Maine river, favoring the formation of the first human grouping during the Roman period, in the 5th century BC (Esnaut, 2016).

In Angers, watercourses served various functions throughout history, similar to Roman cities. They provided essential resources for daily needs and offered cultural, leisure, and religious services (Wech, 2013). Watercourses played a role in recreational events like naumachias, while also supporting structures such as fountains and public baths (Biquet, 2016). Additionally, they facilitated agriculture through irrigation canals (Dermody, 2014).

Since the Roman era, watercourses in Angers have experienced the impacts of urban development, which intensified during the Middle Ages due to increased sanitary loads, waste from commercial and manufacturing activities, urban pollution, and encroachment on the riverbanks (Baptista and Cardoso, 2013). In many medieval cities, including Angers, watercourses were buried under densely built houses, effectively disappearing from the landscape (Coy, 2013). During that time, the Maine River served purposes such as transportation, defense, fishing, energy production, and commerce (Carcaud et al., 2019).

Beyond the fortified city, the landscape surrounding the Maine River and its tributaries retained natural features, exhibiting a wilder aspect and supporting agricultural activities, including vineyards, pastures, gardens, and kitchen gardens of monasteries and country houses (Figure 2).

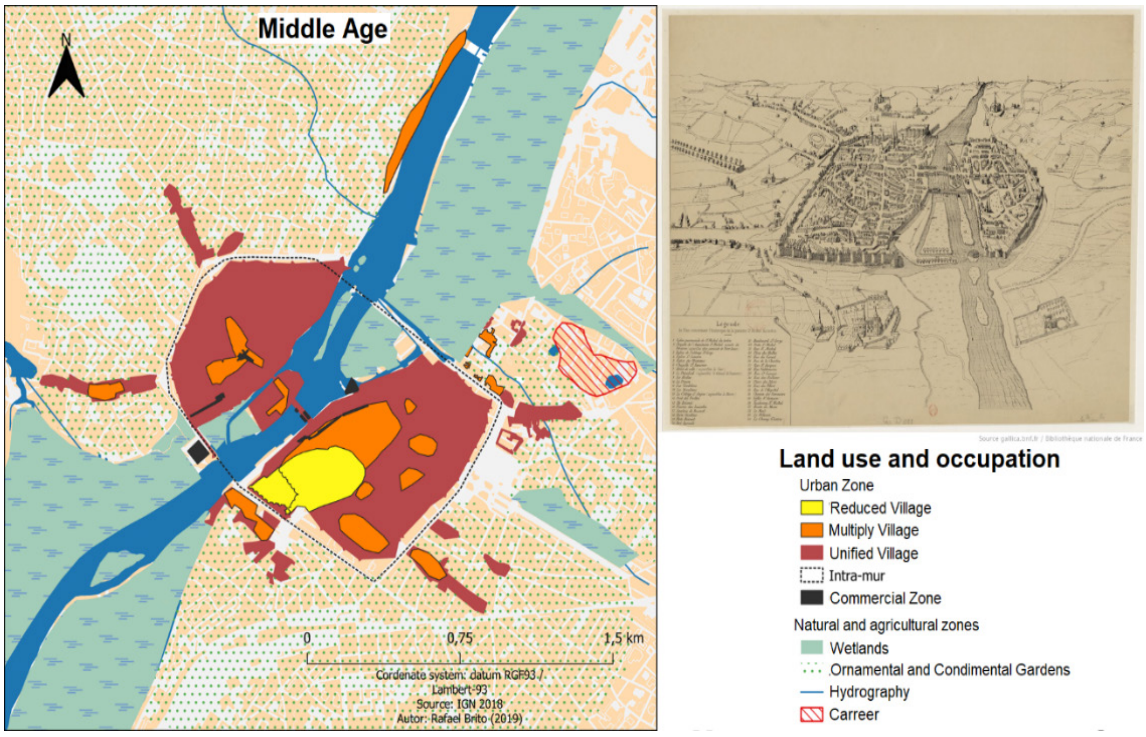


Figure 2. Representative map of the village of Angers and the landscape of its rivers in the Middle Ages (Author: Rafael Brito, 2021, Adapted from Esnaut, 2016 and Carcaud et al., 2019).

The city of Angers remained within the wall and maintained the same characteristics of the 16th century over the next two centuries (Carcaud et al., 2019). The rivers and their banks mainly performed functions of supplying houses, navigation and commerce in the ports, with the landscape surrounding the watercourses outside the city having a more natural and agricultural character in the flooded plains.

Post-French Revolution period, urban expansion and the economic function of rivers

After the French Revolution (1799), the city expanded beyond the walls, modernizing and a strong development of industry occurred. Large works of urban expansion and regularization of watercourses (channeling and drainage) contributed to the economic functions of Maine and its tributaries, significantly altering its landscape. The walls

were replaced by boulevards, connecting the two sides of the Maine River by new bridges to favor its connection with the railway line and the ports. Maine's shores were channeled and stabilized with paved piers (eg Réne-Bazin and Ligny Piers), receiving a set of constructions, such as hotels and commercial houses, to meet the demands of commerce and industry (Biquet, 2016).

Hygienist period - the sources of drinking water

From 1832 to 1854, Angers faced a shortage of drinking water, leading to epidemics of cholera and tuberculosis (Bertoldi, 2015). To address these challenges and improve living conditions, the city underwent modifications based on hygienist principles. These principles emphasized the construction of sewage and storm drainage systems to control floods and prevent diseases (Baptista and Cardoso, 2013).

Thus, many streams and springs in Angers were diverted to the rainwater networks, which were replaced by a network of water distribution sources, in addition to the construction of baths and public laundries (Bertoldi, 1991; Bertoldi, 2000; Bertoldi, 2008; Bertoldi, 2010; Pointereau, 2016).

Industrial revolution and the disappearance of canals and watercourses

By the late 19th century, the urban area of Angers had expanded threefold compared to medieval times, encompassing the entire length of the Maine River's banks. In line with the trends observed in industrialized nations, the urban watercourses, often referred to as "industrial rivers" (Frioux, 2010), were extensively canalized and enclosed within walls. This was done for sanitation purposes and to accommodate the construction of road infrastructure. As a result, the rivers gradually vanished from the urban landscape (Bernhardt and Palmer, 2007; Coy, 2013), and consequently, the presence in the collective consciousness.

Valuing watercourses through the construction of green areas and landscape heritage

In the late 19th and early 20th centuries, the valleys surrounding the rivers in Angers experienced a decline in agricultural and river transport activities due to the modernization of irrigation practices and the rise of road transportation (Montembault, 2004). However, during this period, these valleys began to regain attention as they were transformed into green spaces such as parks, gardens, cemeteries, and public walkways (Mehdi et al., 2012; Bodenan, 2013). The significance of incorporating water elements into the design and location of parks and gardens was already recognized in the 19th century in works like "*Traité général de la composition des parcs et gardens*" by André (1879).

Consequently, numerous green spaces emerged along the rivers in Angers, including the Garden of Plants, Cemetery of the East, Promenade des Fours a Chaux, Promenade de la Baumette, Quay of Savatte, Garden of the Tower of the English, Square Jeanne D´Arc, as well as the protected sites (listed under the law of 1930) such as the meadows of Baumette and Etang Saint Nicolas. Together, these parks and green spaces reflect the heritage value attributed to the areas surrounding the Maine River and its tributaries (ALM, 2019).

The "Glorious Thirty" and the new urban pressure on rivers

During the period of 1945 and 1975, France went through a period of strong economic and industrial activity, known as the "Glorious Thirty". Existing soils in floodplains were explored and landfills were created for the expansion of new blocks. There was also the construction of highways that connect the road network to the city center, in an operation called "Penetrant" (Figure 3) (Carcaud et al., 2019). The place where the soil was removed gave rise to a lake, the Lake Maine (Angers, 2020).

Until the mid-19th century, rivers played a significant role in defining the boundaries of urban growth. However, advancements in technology and the adoption of hygienist principles prompted the expansion of urban areas across rivers and floodplains. As a result, the Maine River and its tributaries were channeled and drained, while the surrounding valleys gained importance as sites for the development of public green spaces.

Sustainable development and the search for the revitalization of water courses

Through participatory and transdisciplinary (democratic) processes, society participates in land management processes, contributing to raising awareness about the importance of rivers and changing habits to reintegrate them into city landscapes (Figure 4).

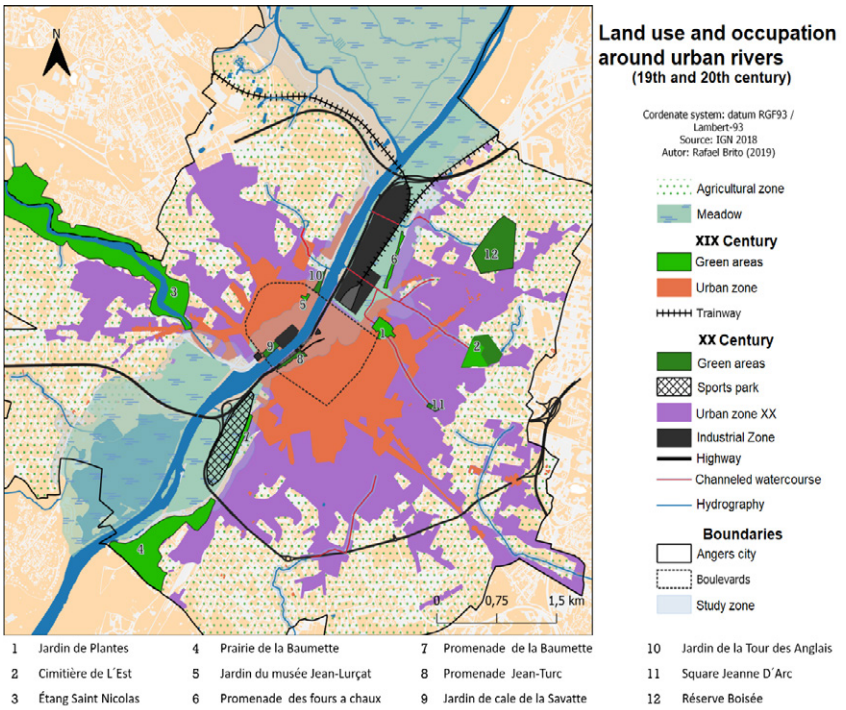


Figure 3. Representative map of urban expansion after the industrial revolution.

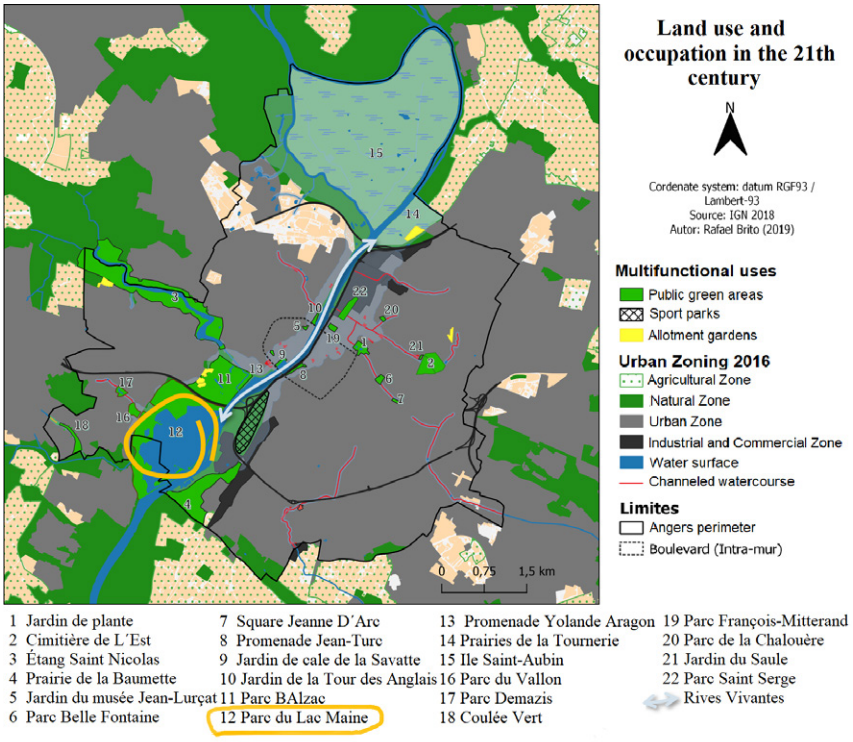


Figure 4. Representative map of the green spaces surrounding the Angers rivers and new projects for the reconstruction of the margins.

Quantitative analysis of land use and occupation around urban rivers (PLUi)

The Local Urban Plan (Plano Local de Urbanismo -PLU) replaced the old Land Occupation Plan to address sustainable development projects, including GBIs and other policies for landscape protection and risk and flood prevention (PPRI) (Cormier et al., 2010).

According to our analysis of land use and occupation, in the study area of 16.26 km², 15% of surfaces are water surfaces, 17% are occupied by buildings and asphalt (impermeable), 12% are occupied by tree vegetation, and 56% are permeable areas that are covered with herbaceous formations, small vegetation or mineral material (Figure 5). Angers retains a significant amount of permeable soil due to the presence of expansive floodplains located to the south and north of the city. These areas, known for their ecological significance and biodiversity preservation, have managed to maintain their accessibility while implementing low-impact infrastructure, and can be classified as green areas (Garcia et al., 2021).

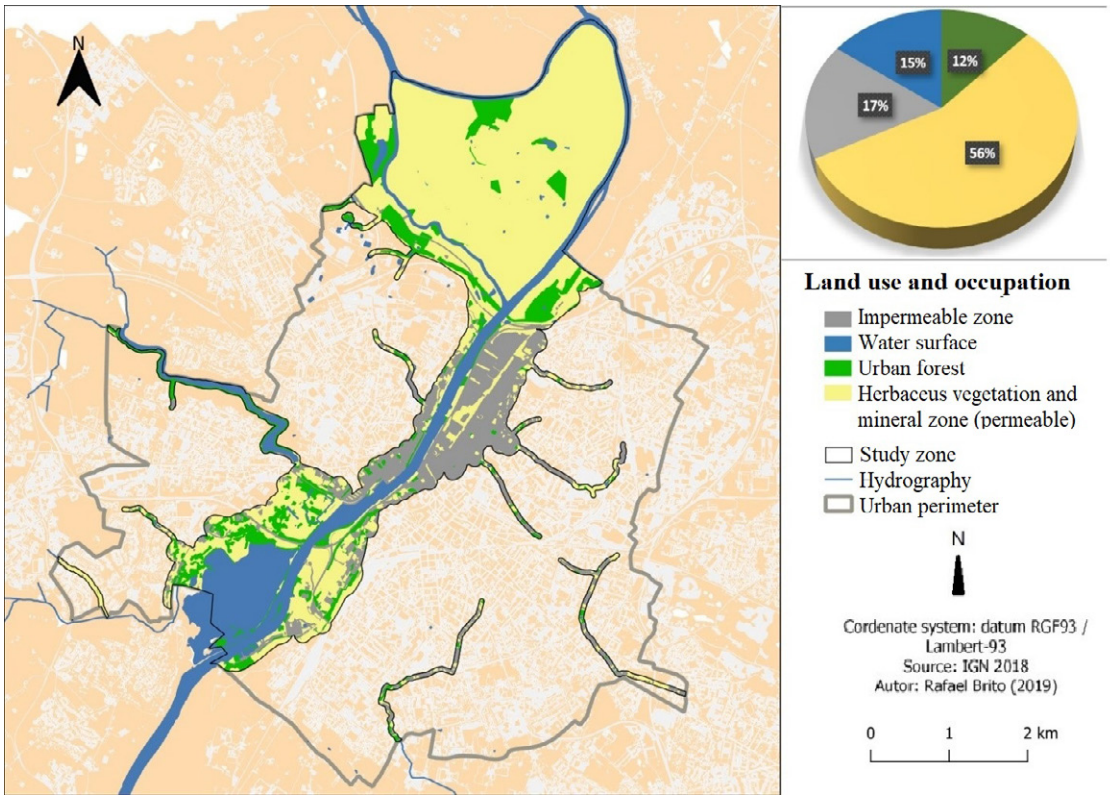


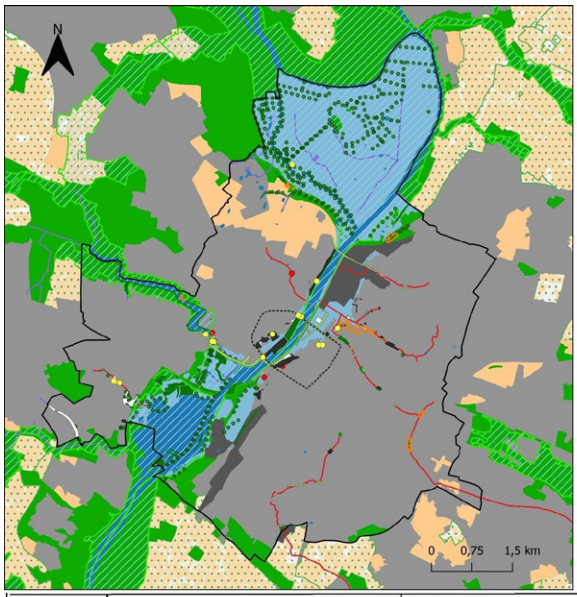
Figure 5. Land use and occupation map with the classification of built-up areas (impermeable) and permeable areas that are covered or not with tree vegetation

The concentration of impervious areas in the central and industrial zones (Saint Serg) is due to the strong occupation (Figure 5) that occurred mainly in the mid-1960s (Carcaud et al., 2019). The choice to implement GBIs has contributed to the maintenance of these permeable and multifunctional areas.

The new urban planning documents (PLUi) have guided recent legislation, in particular, its focus on the identification and preservation of the vegetation heritage of the territory and its definition of a GBI (PLUi, 2017). The plant components provided by the urbanism code are present in the surroundings of urban rivers and contribute to the appreciation of these spaces (Figure 6).

Following the implementation of the PPRI, the implementation of green spaces within unurbanized areas has become an integral part of the mitigation of urban risks (natural and anthropic) (Lotfi, 2017).

Angers has 6.1 km² of green areas, accounting for 14.28% of its total area. These green spaces are strategically distributed to ensure that every resident has access within a 500 m radius (Angers, 2019). In comparison, the city of Newark in the US has municipal legislation mandating a minimum of 7% to 17% of urban territory for public parks, depending on population density (Garcia et al., 2021). In Angers, nearly half of these green areas (48.95%) are located near rivers, taking various forms such as ecological reserves, parks, gardens, squares, and sports parks, among others (Figure 7). The city has received recognition from the UNEP as one of the greenest cities in France, with a ratio of 51 m² of green area per inhabitant in 2011 (Palmares, 2020). Similarly, the city of Newark boasts a comparable index of 50.2 m² per inhabitant (Garcia et al., 2021). Both cities enjoy ample provision of green spaces and large parks within their urban networks.



Urban plan zoning around rivers

Cordenate system: datum RGF93 / Lambert-93
Source: PLUi 2017
Autor: Rafael Brito (2019)

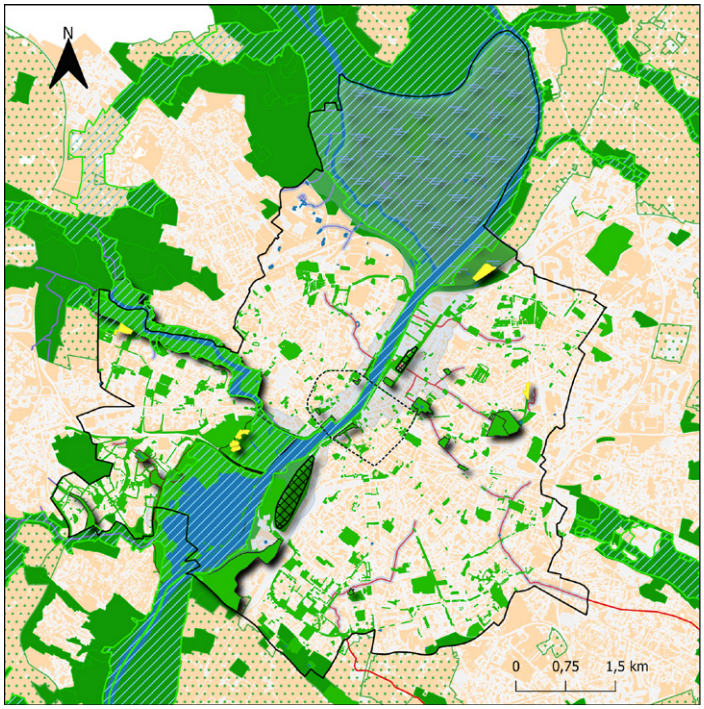
Zoning
- Agricultural zone
- Open area for urbanization
- Natural Zone
- Urban zone
- Industrial and Commercial Zone
- Water surface
- GBI Angers
- Patrimonial monuments

Risk zone
- Area at risk of collapse
- Flood zone

Limites
- Angers perimeter
- Boulevard (Intra-mur)
- Channeled watercourses

	Vegetal components	Dimension related to Angers (ha/Km/ quantité)	Dimension around rivers (m²/km/quantité)
	Protected forest spaces	115 ha	527.943 m²
	Patrimonial gardens	3,5 ha	6.688m²
	Protected landscape zones	50 ha	120.810m²
	Structuring axes of the landscape	107 ha	245.297 m²
	Significant urban forest	41 ha	91.991m²
	"Heart island" (backyards in poorly permeable areas)	5 ha	703m²
	Remarcable trees	88	23
	Aleas hedges and tree alignments	61 km	45,76 m²

Figure 6. Representative map of the PLUi zoning plan around the rivers, with the different plant components and risk areas of the rivers.



Multifunctional uses of urban rivers and its borders

Cordenate system: datum RGF93 / Lambert-93
Source: IGN (2018);PLUi (2017); Cadastre Vertes de la Ville d´Angers (2019)
Autor: Rafael Brito (2019)

Multifunctional uses
- Allotments gardens
- Green areas around rivers
- Sport parks
- Urban Green Areas

Zoning
- Agricultural Zones
- Natural Zones
- Green and Blue Infrastructure
- Water Surface

Limits
- Channeled Watercourses
- Study Zone
- Boulevard
- Angers Perimeter

Figure 7. Representative map of the multifunctional uses of rivers and their surroundings in composition with GBIs.

The French government has proposed connecting its cities and their inhabitants to natural and agricultural areas through GBIs at different scales (local, regional, national and continental). The difficulty in implementing GBIs in French cities stems from the recognition, still recent, of the role of ES in urban planning projects, which have difficulty collating quantitative data (vegetated spaces, population, carbon stock, etc.) with qualitative data (perception, representation, opinion, etc.) (Lotfi, 2017).

Qualitative analysis: Questionnaire and semi directive interviews

Concerning the total of 433 questionnaires' respondents, 24% were men, 75% were women and 1% chose not to identify themselves. The ages of the interviewees ranged from 18 to over 75 years, with young people aged 18-25 years accounting for 30.7%. Adults aged 26-60 years accounted for 60%, elderly adults (over 61 years) accounted for 9.2%, and only 2% were older than 75 years. Among the respondents, 57% were residents of Angers and 80% of these respondents lived in neighborhoods bordering the Maine River.

The average income of the respondents was between less than minimum wage (SMIC) and 3,000 euros, which corresponds to the lower middle and middle classes in France and represented 87% of the total sample.

The five places most cited by the respondents as preferred to enjoy nature and rest are Park du Lac Maine (48.5%), Park Saint Nicolas (47.1%), Park Balzac (43.8%), Aubin (34.4%) and Jardin des Plantes (33.2%), all of which are located near or around a river. The least cited were unrelated to rivers, i.e., located in blocks that do not border the Maine River or at points that are distant from it. When walking through these sites, 68.36% reported paying attention to animals and plants, and 13.16% reported taking advantage of nature without necessarily paying attention to plants and animals. Experiencing nature is a strong reason that leads people to frequent green areas (Salgado et al., 2016; Giannakis et al., 2016; Sousa et al., 2022).

To obtain the opinion of the respondents, who needed to identify three additional pleasant environments, we presented them with images of A) a wooded and gardened square, B) a lake with surrounding vegetation, C) a river and its floodplain, D) a wooded sidewalk, E) a sidewalk with benches and gardens in its surroundings that is close to a circulation road and F) a source with trees in its surroundings. The image with the highest selection frequency was of a lake with surrounding vegetation (92.1%), followed by a wooded and gardened square (86.6%). In contrast, the image showing a sidewalk with benches and gardens in its surroundings near a road was the least selected (19.6%).

Two of the options that were preferred by the respondents showed water in more natural ways in a landscape (lake, river): 90.5% of the respondents confirmed this importance. Water plays an important role in the attraction to green spaces and their contribution to human health (Chen et al., 2020; Zhang et al., 2021; Sousa et al., 2022). When asked what Angers' rivers and streams they knew best, most of the respondents identified the Maine River (82.2%), Mayenne River (36.5%) and La Sarthe River (33.7%), which are larger in water volume, followed by the Jardin de Plantes (24.9%) and Brionneau (15.7%), which are smaller.

The main relationship between the respondents and the rivers and their banks in the city that we established is contemplative use (74.36% of respondents) (Figure 8). Among the respondents who said that they did not like rivers, 7% justified their choice due to poor water quality, while 3% just did not like them.

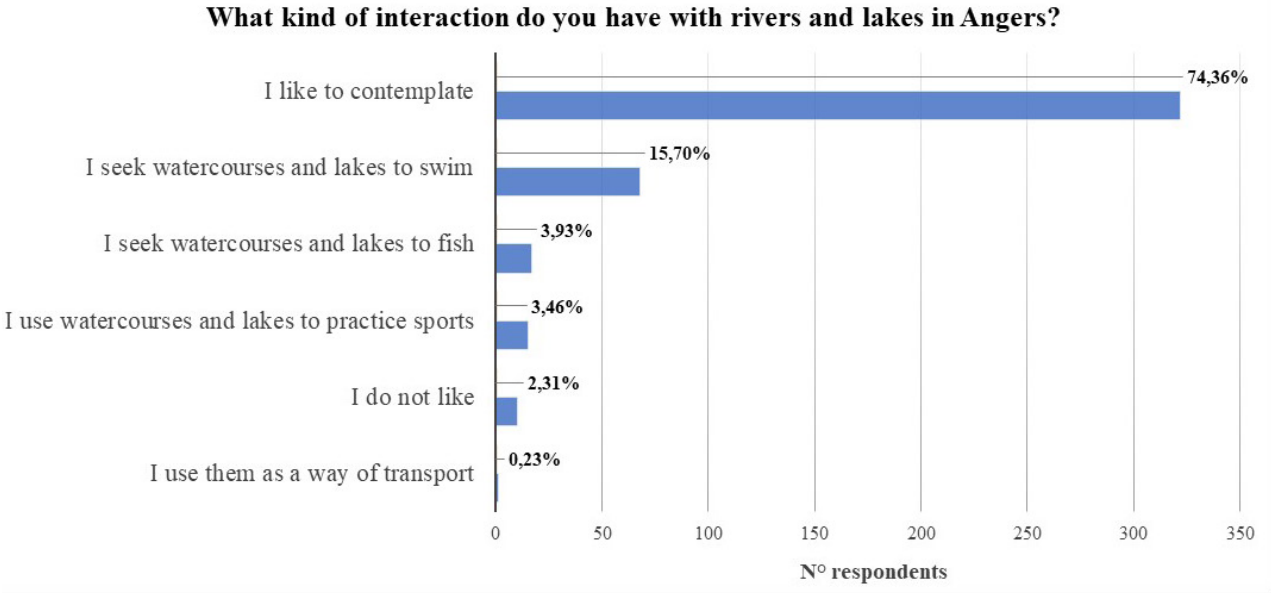


Figure 8. Most common uses of the Angers' rivers according to the respondents

Notably, people who live near multifunctional areas use green areas more frequently (Soga et al., 2015), a use that is favored by the implementation of the GBIs in Angers.

For this integration of landscape and city to occur, it is also necessary to value the quality and accessibility (adequate infrastructure) of green areas. Regarding the quality and accessibility of the landscapes around the Angers' rivers, 57.2% of the respondents considered them satisfactory and accessible, 26.3% considered them of satisfactory quality but difficult to access, 15.2% disapproved of their quality but considered them accessible, and only 1.1% considered them both unsatisfactory and inaccessible. Thus, the Angers government has clearly invested in improving the quality and accessibility of the city's rivers in its program to restore its margins, as discussed above.

In another question, which asked how the respondents could participate in the management of the spaces around the rivers, revitalization and protection with restricted access was suggested by 46.6%, followed by a suggestion to build bicycle paths for better access and utilization (45.9%). As of 2019, Angers had 215 km of bicycle paths in its municipal territory (Angers, 2019); at the regional level, more people in Angers use bicycles to commute than in others (Barré and Besnard, 2017). For the respondents, the least indicated action was the closing and channeling of rivers (1.4%) (Figure 9).

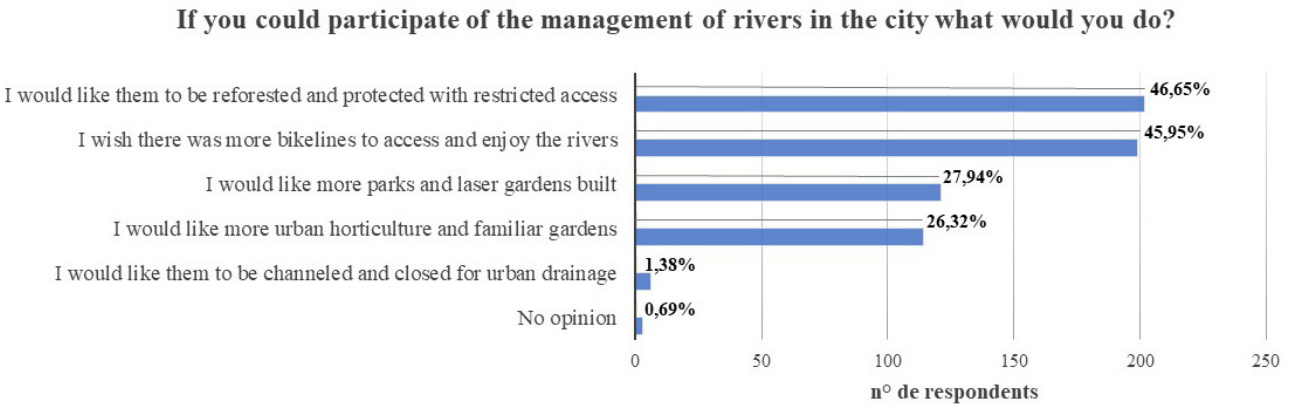


Figure 9. Representative graph of what the respondents would like to be built around the rivers in Angers

The areas surrounding the rivers have been used to encourage the practice of agriculture through the construction of urban and family gardens (Angers 2019). Analysis of the profiles of the respondents, specifically, their contact with a field or agriculture, clarifies that 90% have lived or had close contact with life in the field, while 10% have not had this experience. Additionally, 59.35% had a garden; for those who did not have a garden, their justifications were mainly a lack of space (26.8%), lack of money (7.4%), or lack of time (2.7%), although 68.2% stated that they like plants and animals.

When asked if they knew about shared and family gardens in Angers, 43.2% indicated that yes, and 56.8% answered no. Associations that are linked to the promotion of urban agriculture, such as the Maison d´Agriculture Urbaine (MAU), have promoted annual meetings between producers and citizens to make gardens better known and agriculture more practiced in the city. Interestingly, when asked to indicate a type of construction around urban rivers, 25.8% of respondents indicated family and shared gardens.

Regarding the habits of the respondents, which also indicate their preference for places of consumption, their preferred places for purchasing fruits and vegetables were markets (44.8%), followed by supermarkets (32.3%). Their preference for markets highlights their value of local products and contact with their producers, i.e., the premises of urban agriculture. Moreover, supporting their preference for local products, 84.7% stated that would buy local products produced near their homes, 25.4% stated that they would not buy them, and 7.6% did not know how to express their opinion.

Interviews

To identify the perception of the main actors in the territory regarding the GBIs in Angers, we conducted interviews with representatives of civil society associations, such as the Bird Protection League (LPO) (Representative 1); representatives of the private sector, such as representatives of the Association of Commerce and Industry (CCI) (Representative 2); and representatives of the public sector, such as the head of works at the Park and Garden Directorate (Representative 3) and elected representatives overseeing Ecological Transition and Displacement (Representative 4). The integration of the river into the city depends on factors such as the economy, communication and transportation methods, urban expansion projects, public policies, and the behavior of the inhabitants (Coy, 2013).

Regarding human behavior, the representative of the LPO stated that one of the main difficulties is to change the view of people regarding GBIs:

[...] *there is human pressure that causes all corners to be colonized and occupied by them... they cannot stand the idea of letting a space evolve naturally; they will see it and think it is dirty and poorly cared for*.

Similarly, the representative of the Angers Park and Garden Directorate expressed that it is difficult to sensitize people to the importance of GBIs. However, we have found that society seems to value green areas, as 90.53% of the respondents to questionnaire indicated. The representative stated the following:

[…] *The difficulty lies in being able to show that since we are in a flooded area, for example, the interest of this land for the construction of a GBI is more important than any interest in building housing, commerce or industry*.

According to the other actors, such as the one in charge of the Ecological Transition and Displacement of the municipality, the difficulty in moving from theory to practice is due to the need to change the habits of the population in relation to the environment:

[…] *the difficult thing is to change from good intentions to good practices, because society must change its habits, which is sometimes more difficult than changing legislation* (Respondent 4).

According to the CCI representative, one of the elements that has driven companies to advance their strategies in relation to the protection of natural resources, such as water, is the behavior and demand of a population.

Indeed, despite the high environmental awareness of some societies, most of their members do not see themselves as part of the environment, and they do not relate their daily lives and their attitudes to environmental issues (Milanez, 2009).

The public authorities of several cities have already realized the potential of the areas surrounding rivers to perform large works in the common interest, such as GBIs, to improve the image of their cities and, consequently, their attractiveness to high-quality investments (Coy, 2013; Lotfi, 2017; Sousa et al., 2022). In addition, these areas have been recognized as important not only for their biological richness, which contributes to a beneficial connection between green spaces but also for their ability to contribute to the reduction in risks related to climate change (Sepe and Gomes, 2008).

According to the representative of the Angers Park and Garden Directorate, the city is privileged in terms of its GBIs and ecological connectivity due to its geographical particularities. Currently, Angers has the *Park des Ardoisières* and *Etang Saint Nicolas* in the east/west direction and the Saint Aubin Island to the north; the latter connects to the Loire Valley to the south through Maine Lake Park and then to Maine River itself.

According to the person responsible for ecological transitions, in France, in addition to the competence of the state and region, approximately 30% to 40% of the actions related to the implementation of a GBI are the responsibility of a city. Thus, it is important that there is political sensitivity to the issue in local governments. According to the Director of the Association of Commerce and Industry:

In terms of national policy, laws and regulations are the same, but the political sensitivity of local governments means that they are not at the same level; some have a logic of impermeabilizing and concentrating cities at the expense of nature, while others have greater sensitivity to the construction of green spaces and lower housing density.

According to the representative of the Park and Garden Directorate of Angers, the most effective means for the implementation of a GBI are urbanism, sensitivity and political will, which aligns with Cormier et al. (2010). According to the CCI representative, in addition to legislation and political sensitivity, the awareness of economic actors is important:

[…] *In the last 10 years, the priority has been given to economic development and perhaps a little less to the environmental. We feel that after a few years there will be an environmental awareness that is made a little by the legislation and contracts, but I also think that it requires an awareness on the part of the managers of companies to find a balance […] We are late, in the Pays de la Region Loire, at addressing the issue of water resource management. [Our resources] are highly polluted, we have conflicts between agricultural, economic, human and population use, and we feel that recently, i.e., as of 2 or 3 years ago, the issues of water resources and repeated droughts have become a big question*.

This awareness of Angolan actors has already produced effects through projects including the "Living margins" "and "Requalification of Lake Maine". However, these economic actors recognize that there is still much to be done in relation to water resources.

When asked about what companies have been doing in relation to environmental policies and improving the quality of Angers' rivers, the CCI representative stated that for more than 20 years, the integration of environmental policies within industrial and commercial activities in Angers has been accomplished. However, the issue of water resources has been neglected, requiring greater attention:

In the last 2 or 3 years, the trade and industry association has been working on water resource management, seeking to accompany companies in their implementation of sustainable solutions, such as the use of renewable energy, everything that involves a circular economy, limiting waste and reusing it for other purposes, and the management of water resources through a reduction in consumption and a return to better quality water.

In addition, in France, there is a corporate social responsibility (CSR) policy that was proposed by the European Commission; it highlights the "responsibility of companies for their effects on society" and aims to change the behavior of companies in favor of sustainable development.

Although sensitivity to the issue of rivers and their surroundings has affected different spheres in society, according to the representatives of the CCI and the Ecological Transition and Displacement department, there are still groups that maintain interests that are contrary to those proposed by the GBIs.

Although the sense of urgency to find solutions is strong, society is still looking for a sustainable way to act. Thus, these challenges need to be addressed by a joint and diverse ecosystem of private actors, universities, civil societies and politicians (Baccarne et al., 2016; Sousa et al., 2022).

Analysis of the questionnaires and interviews shows that Angolan society is moving toward a general awareness of the ES that is provided by Angers' rivers and their surroundings to the city. Despite the conflicts over use and interests that still exist, public and private actors have been sensitized to the issue of urban rivers and have sought alternatives that can contribute to their reintegration into the urban landscape, thereby meeting the desires of the population, who engage in participatory processes and democratic decisions.

Conclusions

The geohistorical analysis conducted in Angers reveals that the landscapes of its rivers have undergone transformations over time, with the industrial period witnessing significant channeling and alteration of rivers and urban streams to prioritize economic functions over natural and social aspects.

The restoration of the natural and social functions of rivers is possible to achieve through sustainable development policies that incorporate the notion of green and blue infrastructures into a local urbanism plan. In this research, we have revealed in the design of green spaces the possibility of a balance between their functions that tend to favor multifunctionality. This has been possible through the determination, in the urban planning documents, of the landscapes of rivers as urban heritage through the identification of the plant components that compose these landscapes.

Interviews with public actors in Angers demonstrate their awareness and understanding of the ecological connectivity and flood control provided by rivers and their surroundings. Private actors are also actively seeking sustainable alternatives, such as adopting circular economy practices, which can contribute to improving river quality and enhancing the well-being of residents.

The inhabitants of Angers express positive opinions regarding the integration of rivers into the urban landscape, supporting multifunctional solutions like green and blue infrastructures.

Given that water is essential for life, ensuring the good quality of rivers is crucial for both economic development and the overall quality of life. Recognizing the vulnerability of rivers and their banks to the impacts of climate change, Angers incorporates them into its urban territory management. Participatory and transdisciplinary processes foster broader societal awareness of the multifunctional role of rivers, reintegrating them into the urban landscape and enhancing the well-being of its residents.

Author Contribution

RBS: Project development, methodology, data collection, statistical analysis, writing the original draft. **PDOP**: Methodology, project development writing, review, and editing. **MVR**: Methodology project development, writing. **NC**: Methodology, project development, writing, and review.

Acknowledgments

This work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES), the National Council for Scientific and Technological Development (CNPq), and of the Minas Gerais Research Support Foundation (FAPEMIG), and the laboratory UMR(6590) ESO-Angers. We are very thankful to the Graduate Program in Plant Science of the Universidade Federal de Lavras for providing de Doctorate Sandwich Program and Cotutele MoU.

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- Former president of the Association for the Protection of Birds (LPO). Angers, July 7, 2020. (Interview to R.B. SOUSA)

- General Manager of the Association of Commerce and Industry (CCI). Angers, July 10, 2020. (Interview to R.B. SOUSA)

- Head of Services and Works at the Parks and Gardens Department. Angers, October 9, 2019. (Interview to R.B. SOUSA)

- Elected in charge of Ecological Transition and Displacement. Angers, June 30, 2020. (Interview to R.B. SOUSA)