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Agroforestry Contributions to Urban River Rehabilitation

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Abstract: The context of urban rivers is one of pollution of their courses, the degradation of riparian habitats, the loss of biodiversity, and the marginalization of the human populations that live next to them. Due to urban growth, the hydrological dynamics in entire basins and the hydromorphology of rivers are changing. This situation increases flooding, decreases the availability of water for human use, and disconnects the rivers from the dynamics of the city. Agroforestry is the integration of cultural, wild, and domesticated diversity with use, conservation, and restoration objectives. These practices in cities can contribute to addressing the problems mentioned. We analyze agroforestry practices and the socio-ecological contributions to urban river rehabilitation. We review 37 experiences worldwide. Agroforestry practices included in the review are trees and hedgerows; wetland agroforestry; aquatic, botanical, edible, educational, and rain gardens; bioswales; green parking lots; food forestry; vegetation in alleys and streets; vertical terrace walls, among others. Agroforestry contributes to efforts to solve urban river problems, improve water quality and access, restore riparian habitats, enhance river hydromorphology, support local economies, and create a river culture. We emphasize promoting multi-relational people–river interactions based on theoretical and practical frameworks that integrate diverse disciplines, perspectives, and experiences.

Keywords: mixed-uses; public spaces; urban and peri-urban agriculture; recreation; human–nature connection; green–gray–blue infrastructure; nature-based solutions

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1. Introduction

Most rivers in the world suffer from pollution, fragmentation, and overexploitation. Only one-third of the rivers in temperate and tropical zones are still free-flowing [1]. The growth of cities has led to changes in land use, resulting in the proliferation of impervious covers (cement, pavement, etc.) that alter the hydrology and geomorphology of rivers [2,3]. Urban streams are recipients of sewage and solid waste, which are a cause of health problems. All of these impacts have led some authors to propose the term "urban stream syndrome" [4], which describes the ecological degradation that is consistently observed in streams draining urban land.

Among the concepts most frequently used in the literature on interventions to recover the ecological functions of rivers are: rescue, remediation, rehabilitation, and restoration [5]. Restoration is the most radical form of interaction since the objective is to return the ecosystem as much as possible to its original situation before humans acted on it [6,7]. However, it becomes complicated to think of restoring a river to its original ecological state [5]. In these cases, it is more appropriate to use the term "rehabilitation" since it focuses on recovering important socio-ecological functions and allowing the river to be incorporated nicely into the city's landscape [8]. The river becomes a green corridor built and developed from the city's rivers [9] and water bodies to transform densely populated areas into attractive spaces [5,10,11]. Most studies on the recovery, restoration, and rehabilitation of urban rivers have focused mainly on ecological aspects [2,4,12]. However, considering socio-cultural factors is of great importance for the rehabilitation of rivers in cities [11,13,14]. In turn, the rehabilitation of urban rivers is an opportunity for urban restructuring [15] and for enhancing local wellbeing [16].

The rehabilitation of urban rivers has been approached through ecohydrology [15,16], new urbanism [8], the "sponge city" [17,18], green infrastructure [19], and "nature-based solutions" [20]. These approaches propose the integration and management of both natural and human-made elements to recover river functions. Agroforestry is the integration of cultural, wild, and domesticated diversity to benefit from the interactions of such integration [21]. The term agroforestry also designates systems and forms of land use that incorporate perennial woody plants in the same spatial unit as crops and farm animals [10–13]; it is a system that optimizes ecological and cultural interactions among its elements [22]. These strategies allow for the conservation of native wild species and cultivated species, as well as the biocultural landscape and environmental contributions in the areas where they are found [10,12,14,23,24]. Their importance for subsistence, the local and family economy, and the cultural identity of the population that practices agroforestry is also widely recognized [25–30]. Agroforestry provides an alternative way of thinking about human–nature interactions that promote connections to re-establish ecological functions and integrate human activities and aspirations with the natural dynamics of rivers in cities. According to the literature, agroforestry is the most appropriate model for the recovery and conservation of forests, jungles [7], and wetlands [1,2,31,32].

Urban agroforestry (UAF) refers to the interactions of urban dwellers with trees, crops, and associated fauna and microorganisms in various areas (parks, sidewalks, rivers, gardens, rooftops, etc.). UAF generates socio-ecosystemic contributions to local human communities [33–37] and urban ecosystems [33]. It also creates a "river culture" where rivers are an essential part of life in the city [38]. For this reason, the integration, theoretical frameworks, diverse methods, and perspectives on urban river rehabilitation are a necessity and an opportunity for urban rivers. Urban agroforestry is an essential contribution to such approaches and methodologies, and it deserves to be studied and recognized.

The literature on urban agroforestry contributions to urban river restoration and rehabilitation projects is scattered in various repositories (the term does not appear as a category on its own, but rather as a variety of practices, such as "bioremediation", "wetland", "trees", "native plants", or "food garden" in the case of the Landscape Performance Series repository, https://www.landscapeperformance.org/, accessed on 22 May 2022). This information is part of the recent interest in the importance and contribution of urban green areas to the health of cities. The number of publications on "Urban Open Green Spaces" increased from 50 publications in 1997 to more than 500 per year in 2015 [39]. The rehabilitation of urban rivers and streams is an established trend and recognized as an efficient way to promote welfare in cities [23,40]. However, the benefits resulting from the rehabilitation of urban rivers to the quality of life of urban dwellers have received little attention, as the emphasis has been on pollution control, flood control, drainage works, and urban development [41].

This paper addresses the general question: How does agroforestry contribute to the rehabilitation of urban rivers? The particular questions are (i) What are the problems related to rivers in cities? (ii) What experiences exist in the rehabilitation of urban rivers around the world? (iii) Who carries them out, and what strategies and actions do they implement? (iv) What is the relevance of agroforestry practices in these experiences? and (v) How does agroforestry contribute to the necessary processes to achieve the goals and social and environmental aspirations of the rehabilitation of urban rivers? This work contributes to a comprehensive agroforestry approach to river rehabilitation in urban contexts (See Figure 1) by researching and reviewing not only the literature on theoretical frameworks and concepts but also reviewing 37 experiences around the world and the actions that they implement to respond to the challenges in urban river rehabilitation.

Section 3.1 provides a summary of the problems of urban rivers. Section 3.2 analyzes the experiences reviewed, showing how experiences respond to the issues described in Section 3.1 and contribute to rehabilitating urban rivers. Section 3.2 organizes the actions implemented based on their contribution to the processes identified and defined as the socio-ecological goals and aspirations of urban river rehabilitation (See Figure 1). The aims and aspirations of the study are based on the review and synthesis of the problems and the main concepts of rehabilitation of urban rivers found in the academic and institutional literature. The conclusion ends with a reflection on agroforestry's future needs and prospects in urban river rehabilitation efforts.

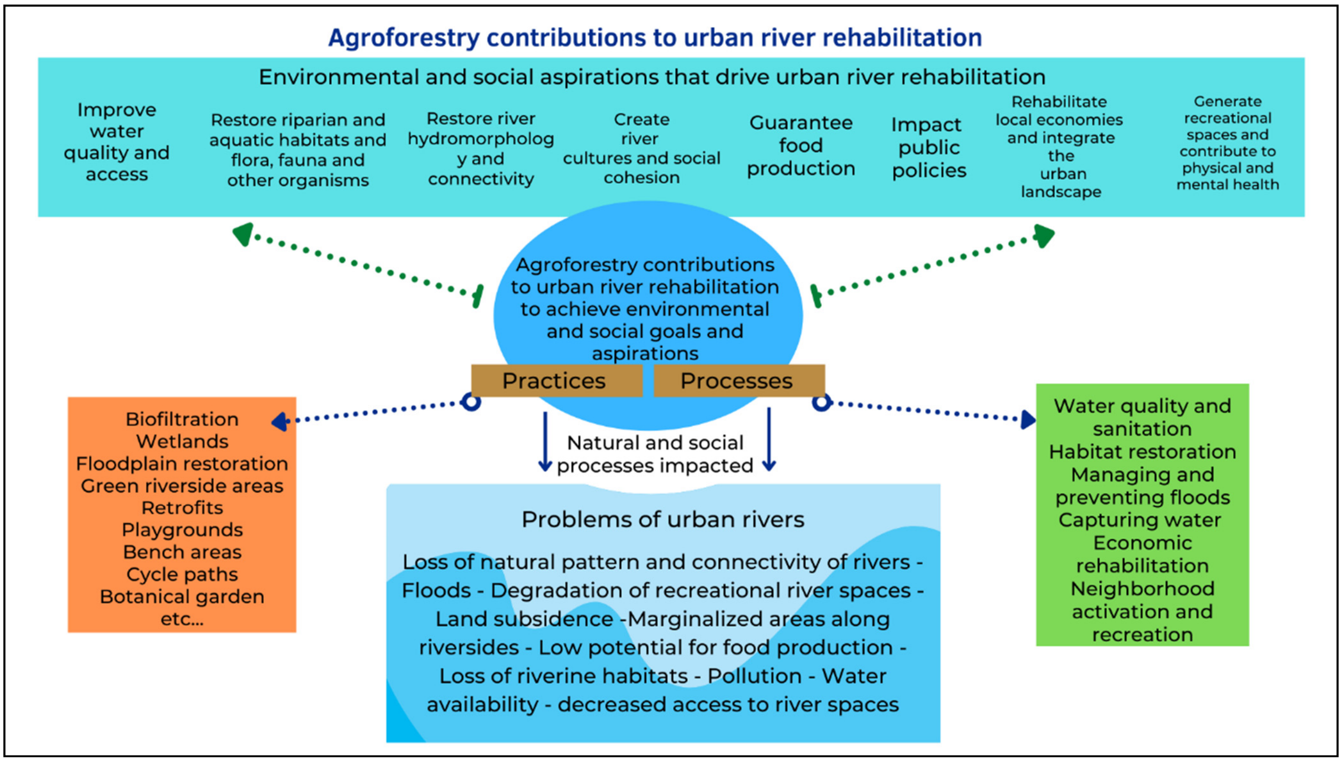

Figure 1. The research focuses on learning about the main problems faced by rivers in cities, the state of the art in urban river rehabilitation from different frameworks and disciplines, and the contributions of agroforestry to real experiences around the world that aim to achieve social and environmental goals and aspirations of urban river rehabilitation, and the processes necessary to achieve this.

2. Methods

The review began with a search in Google Scholar and other specialized databases such as SciELO and World Wide Science to find out what kind of literature and content we could find based on the Spanish terms: "agroforestería, rehabilitación ríos urbanos" (1700 results in Google Scholar) and in English "agroforestry, urban river rehabilitation" (11,200 results), "agroforestry, urban river restoration" (19,700 results), "ríos urbanos" (117, SciELO), "urban river rehabilitation" (318 outcomes, World Wide Science), and "silvicultura, ríos urbanos" (silviculture, urban rivers) (Google Scholar, 21,800 results). Based on the first results obtained by these search engines, we selected the 40 publications most related to the question that this review aims to answer.

After reading the first selected articles, we continued the literature search by applying a "snowball" method, identifying the main topics discussed in the documents found, and following the references and authors in the reviewed works. We reviewed 120 publications, repositories, and web pages in-depth. In addition to the information found in scientific journals, we conducted a broader search from other sources, such as social networks, web pages, and local media. We analyzed and integrated the information through the qualitative analysis software Atlas-Ti version 9.0 [42]. We generated codes to organize the information into categories regarding the problems of rivers in cities, existing experiences, agroforestry practices used, and their environmental contributions.

In a second phase, we searched for the most important problems of urban rivers and, based on this information, defined where socio-ecological processes are being impacted by the problems presented in the literature. After we defined the processes, we organized the information on the experiences based on how they deal with the identified problems and which practices were implemented to tackle them.

We organized the information on the experiences in a database (Supplementary S1). This annex presents the 37 selected experiences, locations, practices, actions, and strategies. These were selected based on the completeness of the information related to the questions of this research. Supplementary S2 presents the sources of information classified according to the type of source. We spatialized this information in the map presented in Section 3.2, which can also be found in the supplementary files. Additionally, included in the supplementary files is a glossary (Supplementary S3) that offers a definition and description of the actions and practices implemented in the experiences reviewed.

3. Results and Discussion

3.1. What Are the Main Problems of Water Bodies and Rivers in Cities?

The main problems of rivers in cities mentioned in the literature include the following:

i. Water availability. According to the United Nations [43], one in three people do not have access to safe drinking water, and 60% of people lack access to safely managed sanitation facilities. In cities in Africa, water availability decreases as we move away from city centers; in other regions, such as Asia, cities have expanded over areas of importance for water access [44].

ii. Water body pollution by direct and diffuse sources [45,46]. Pollutants discharged into water bodies in urban areas represent up to 80% of wastewater [46]. Every day, almost 1000 children die from preventable diarrheal diseases related to water and sanitation. These waters also cause diseases such as cholera and schistosomiasis [47].

iii. Loss of habitat and biodiversity in riparian and aquatic environments [48]. Urban development and channelization of rivers have led to the reduction of riparian vegetation, which affects the water cycle by reducing groundwater recharge, impacting water availability and soil stability (subsidence) [3,11]. Loss of infiltration into groundwater decreases storage, increasing runoff and the speed of stormwater discharges. It also increases stream erosion, flooding, and the concentration and number of pollutants in stormwater [3,49,50].

iv. Loss of the natural pattern of hydromorphology and connectivity of the river due to hydraulic maneuvers [3,49–51]. The loss of wild river vegetation is one of the impacts of urbanization on river hydromorphology [52]. The construction of impermeable surfaces changes the hydrology of the basin, the river flow, and sediment mechanisms, as well as the movement of organisms, which restricts the dynamics of the rivers [53–55]. Hydraulic maneuvers to improve navigation or prevent flooding have also modified the connection of rivers with cities and their citizens [14,17,52,53,55,56].

v. Floods [14,56–59] Flooding in urban areas is caused mainly by a reduction in the infiltration capacity of soils in urban areas [14] due to the construction of impervious surfaces [53] and the consequent increase in the amount of runoff [34,35], as well as deforestation and land-use changes upstream [60]. Approximately 70% of all deaths related to natural disasters in 2018 came from water-related disasters such as floods [43]. In 2050, the number of people at risk of flooding will increase to 1.6 billion in cities [58].

vi. Loss of water bodies and green areas in cities [61] and the degradation of public and recreational spaces connected to water bodies (waterscapes) [41,61,62]. In most of the world's cities, the public open spaces or urban green areas that are available to the general population are small and highly visited, evidencing a significant need for open (green) spaces [61,63]. However, concerns such as litter, pollution, water and river flow safety, and insecurity (crime) influence people's perception of urban rivers. They can be determinant in the acceptance of river rehabilitation projects [41,64] and impact how people access and use these spaces.

vii. Land subsidence [65] is becoming a common problem in many cities worldwide [66–68]. It is "a gradual settling or sudden sinking of the Earth's surface due to removal or displacement of subsurface earth materials," [65] with underground water extraction being one of the leading causes. In addition to the damage to buildings and constructed capital, one of the most pressing problems is the compaction of aquifers to store water [69] which impacts urban water availability.

viii. Marginalized and poverty-stricken areas along rivers [64]. Riverbanks are diverse areas where we can find high real estate value as well as places of great marginality and abandonment. Certain spatial conditions may be a consequence of the lack of government attention to these marginalized areas [64]. These conditions affect access to and use of these spaces and their connection to other areas of social and ecological importance in the cities.

ix. Low potential for food production in connection with urban water bodies [70,71]. Farmers use approximately 70% of all water extracted from rivers, lakes, and aquifers for irrigation [43]. Thebo et al. [71] found that 60% of irrigated cropland and 35% of rain-fed cropland are within a 20 km radius of an urban area globally. However, food production in urban areas poses health risks due to high contamination levels, which has led to a ban on food production in cities such as Sydney [46,72]. Regardless, agricultural practices are typical along riverbanks and floodplains in towns worldwide [72–75]. See Figure 2 for a representation of the problems described and the processes they impact.

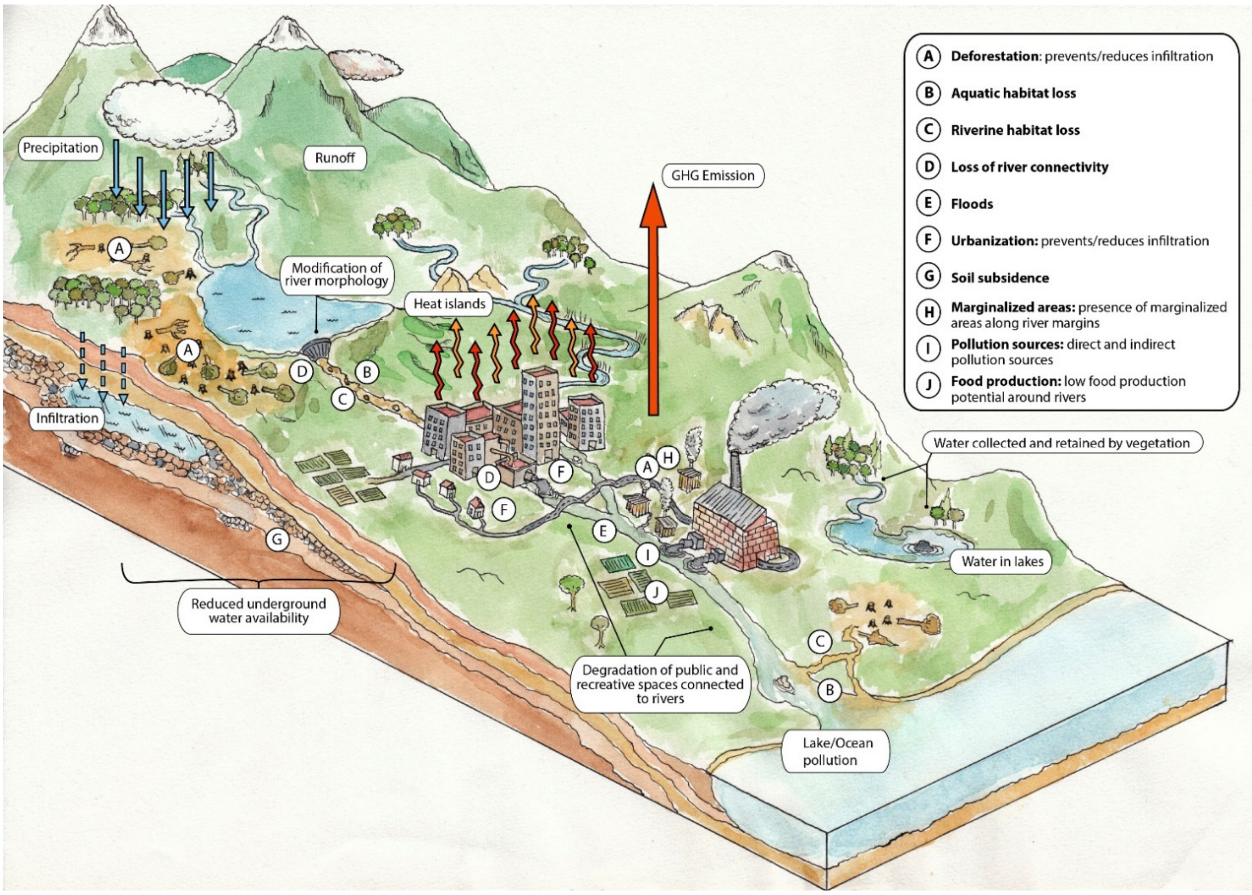

Figure 2. Elements, processes, and interactions in a watershed. The figure illustrates the processes

that are impacted by a variety of human activities that modify eco–hydro–morphological dynamics in cities. Urbanization is one of the main dynamics impacting rivers in urban areas (**F**); the impacts associated with urbanization are many. Deforestation (**A**) in the higher lands of a basin prevents water from infiltrating into underground strata, while the building of impervious surfaces in the cities not only prevents infiltration but also causes water to flow through "super water highways", that is, channels and streets, causing floods downstream (**E**). Coincidentally, many of the populations impacted by floods are also the most marginalized urban or peri-urban populations, with many living on the riversides (**H**). River morphology is affected in many ways, as in dams that prevent water flow or by straightening meanders or channeling them so they can flow through the city landscape (**D**). Pollution sources can be direct (such as direct dumping of untreated industrial waste into water bodies) or indirect (such as runoff from streets which carries oil and worn-off tires from cars, all sorts of garbage and other pollutants that may come from the upper lands, in the form of agricultural agrochemical residues) (**I**). Pollution strongly impacts food production in and around cities (**J**). All of the dynamics above impact aquatic and riverine habitat loss (**B** and **C**). Water availability in cities will be one of the most pressing problems in the near future. Soil subsidence will not only affect the ground structure in the city but also prevent water from infiltrating and remaining stored in the ground for later human use (**G**). This diagram shows only some of the impacts of urbanization on the hydrological cycle in a watershed (Illustration by Gabriel Rico-Lemus, 2022).

3.2. Experiences in the Rehabilitation of Urban Rivers

As mentioned in the introduction, this section offers a description of the experiences reviewed and synthesized and attempts to respond: What experiences exist in the rehabilitation of urban rivers around the world? Who carries them out and what strategies and actions do they implement?; Additionally, what is the relevance of agroforestry practices in these experiences? We focused our attention on how these experiences respond to the problems described in the section above by contributing to the processes essential to achieving the socio-ecological goals and aspirations of urban river rehabilitation projects. Due to space constraints, we offer a description of only some of the actions performed in some of the experiences reviewed. Table 1 synthesizes this information, while all actions implemented in all of the experiences reviewed are described in more detail in the glossary (Supplementary S3). Supplementary S1 also offers information on which actions were implemented in each of the experiences. Map 1, included in the supplementary files (Supplementary S4), shows where the experiences we reviewed are located in the world. Although it is not statistically significant, it could point to where in the world these experiences are more popular and whether they are being documented.

Table 1. Practices in the experiences reviewed and the processes with which they´re associated.

Specific Processes and Associated Concepts	Actions (Practices)
Improve water quality, access, and availability	Aquatic garden Biofiltration "Retrofits" (sidewalk drains to capture rainwater) Construction of marginal drainage for domestic wastewaterConstruction of reservoirs Installation of ultraviolet light treatment plants Permeable pavement Rainwater harvesting Solid waste cleanup Sustainable urban drainage systems

Table 1. *Cont.*

Specific Processes and Associated Concepts	Actions (Practices)
Restore river hydromorphology and connectivity	"Daylighting" streams and rivers Desilting Floodplain restoration Gabion dams Green areas for water management Hedgerow planting and transplanting J-stone paddles Logs to stabilize banks Reconstruction of meanders Re-establishment of connections between streams Removal of concrete barriers and dams Retention ponds Rocks as bridges Tree planting and transplanting Wetlands
Restore riparian and aquatic habitats and flora, fauna, and microorganisms	Bioremediation Construction of fish mating areas Control of invasive species Reintroduction of fish species Reintroduction of native plants Row planting with pioneer species Soil bioengineering Sustainable grasslands planted with native species
Create river cultures	Green riverside areas Pumps to establish a constant flow Shrub planting Planting of grasses Participation of neighbors in planting and caring for plants Food gardens All the actions related to "Generate recreational spaces and integrate the urban landscape" below Compost Educational vegetable garden Environmental education and river cleanup campaigns Blue areas Botanical garden Environmental interpretation signs Ecological zone for environmental education Nature education sites
Guarantee food production	Food gardens Urban Food Forestry
Impact public policies	Fines and incentives on river use across a region Multisector water parliament at a regional level Organization of forums on urban rivers Regulatory changes and water use agreements in a region of Europe
Rehabilitate local economies and integrate the urban landscape	Equine exhibition area Markets Museums Passive and active recreational areas Relocation of families living along the riverbed Re-use of demolition material of old canal structures Sports arenas Stores

Table 1. *Cont.*

Specific Processes and Associated Concepts	Actions (Practices)
Generate recreational spaces and integrate the urban landscape	Bench areas Bikeways Connectivity to other means of transportation Construction of linear and ecological corridor Construction of marshes and low-lying areas Construction of piers or beaches Construction of willow swamps Cycle paths Green parking lots Green riverside areas Large parks or urban forests Mapping Ornamental trees Playgrounds/green schools Public toilets Rain gardens Sidewalk gardens and plantings Trails and bridges, kayak ports Vegetation in alleys and streets Vertical terrace walls

3.2.1. Improve Water Quality, Access, and Availability

Water quality is one of the most critical factors for the rehabilitation of urban rivers since its acceptance [41,61], and the sustainability of habitat conservation and recreation projects will depend on it, especially when seeking to generate activities that require contact with water [61]. River sanitization has been one of the central interventions of the rehabilitation projects. These interventions are generally costly and focus on centralized wastewater treatment but are ineffective due to their high costs [76] and different flows in the river sections. People pay little attention to rainwater management, and the tendency has been to "over-design" the urban system, forgetting that the urban landscape has a "patchy" character, with a gradient of blue–green and gray infrastructure [77].

Managing the interactions between biota and urban river water helps regulate the dynamics and quality of river water [16]. Wetlands include permanently or temporally flooded lands in many different habitats such as rivers, and this vegetation lives in unique hydric and soil conditions [31]. Wetland agroforestry and aquatic gardens are agroforestry practices for improving water quality. They are management systems in an eco-hydrological combination (wetlands and gray infrastructure) and constitute an alternative to wastewater treatment [78,79]. In the experiences researched, some of the implemented agroforestry actions that contribute to water quality were the aquatic garden in Glenstone, Maryland and wetlands in the Colorado River Delta or the Anacostia River in Washington D.C. A "water garden" or "aquatic garden" is a garden or parts of a garden where water dominates as the principal element [80]; In the aquatic garden in Maryland, more than 4000 plants were sawn. Wetlands are unique ecosystems that are either permanently or seasonally inundated with water, supporting species that are adapted to live there, and they encompass a broad range of wet environments that include rivers and streams, floodplains, estuaries and deltas, lakes, ponds, ditches, wet grasslands, marshes, mudflats, peat bogs, mangroves, reedbeds, and coral reefs. The lawns at Glenstone were converted from turf and pasture into sustainable meadows planted with all native species, including little bluestem (*Schizachyrium scoparium*) and purpletop (*Tridens flavus*) [81]. Additional techniques for enhancing water quality include nature-based solutions with a green–gray infrastructure focus: biofiltration (See Figures 3 and 4 below) and detention ponds, retrofits, construction of marginal drainage for domestic wastewater, or the installation of ultraviolet light treatment plants (See Supplementary S1 and Supplementary S3). The use of treated water is considered an effective way to restore ecosystem contributions from rivers [82].

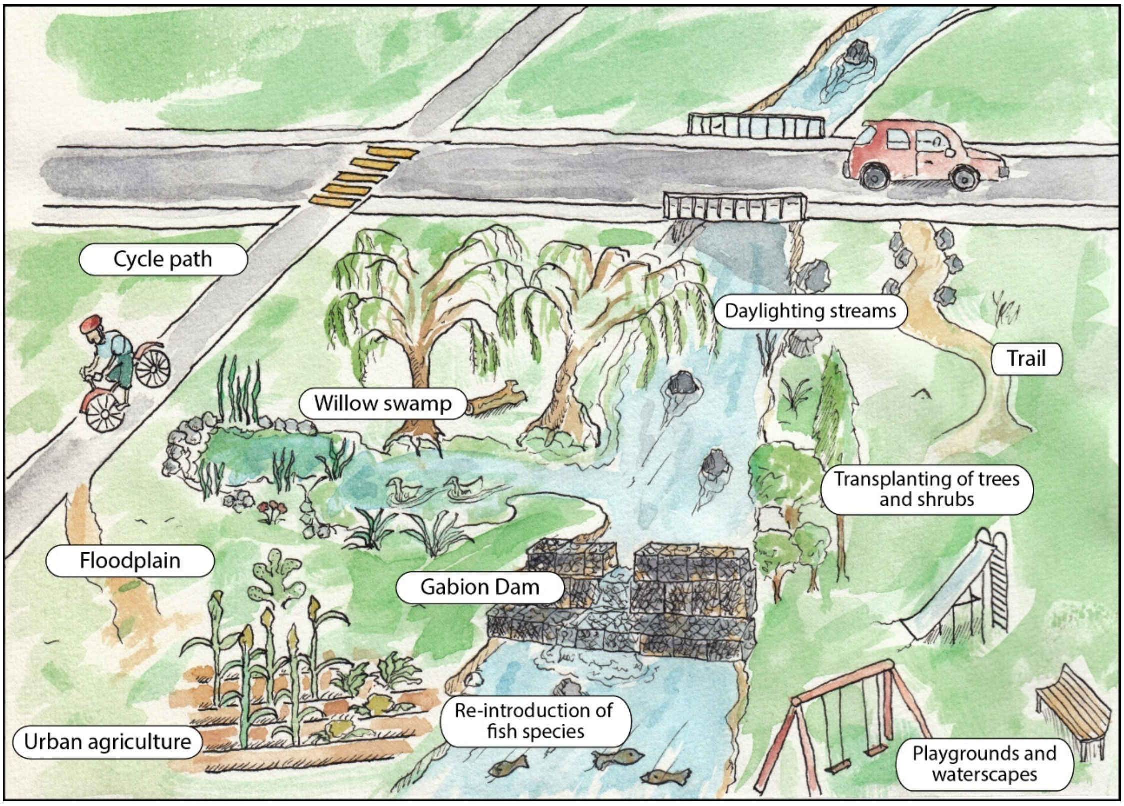

Figure 3. Schematic examples of the actions carried out in the experiences reviewed. As the daylighting of streams occurs in many cities, many other actions are taken to reconnect rivers to cities and habitats, restore riparian habitats, and habilitate recreational spaces. Agroforestry integrated as part of ecohydrology, and nature-based solutions can help treat direct pollution sources through methods such as biofiltration ponds, artificial wetlands, and willow swamps. Gabion dams may help regulate river flow and create breeding spaces for fish. Urban agriculture can utilize river resources and even be part of recreational spaces, together with playgrounds, bike paths, and trails, in a strategy that promotes mixed uses of space.

3.2.2. Restore River Hydromorphology and Connectivity

Agroforestry promotes connectivity between green areas in the city, and it helps expand green places and connect riverbanks with other green spaces in the city [83]. The construction of wetlands through eco-hydrological techniques such as gabion dams [16,77–79,84] responds to the problems of habitat and biodiversity loss by re-establishing connectivity along the river, promoting greater ecological diversity [43] and diversity of spaces and landscapes [40,41,62]. The above allows rivers to return to their natural course [53], which arises from the interaction of water and accumulation of soils and recovering vegetation (sometimes trees and shrubs). In this way, connectivity along the river can be re-established, promoting greater ecological diversity [39] and diversity of spaces and landscapes [40,41,62].

In the case of the Santa Cruz Riverbank and Ecosystem Restoration case, habitants planted 10,000 trees and cacti. They fused a traditional gray infrastructure with a nature-based approach to control and manage erosion [85]. In other cases, citizens habilitated green areas such as rain gardens, bioswales, or green parking lots for water management [86]. Some of the actions implemented in the projects reviewed were the "lighting" of streams and rivers (see Figure 3 above) and the removal of concrete covers to make urban streams and rivers more visible [87]. The city's inhabitants improved the flood plains and the green areas for water management, and they reconnected meanders and streams and built retention ponds and rock bridges (See Figure 5 below). The agroforestry practices used were the planting and transplanting of trees and hedgerows and the creation and rehabilitation of wetlands (See Supplementary S1 for specific examples).

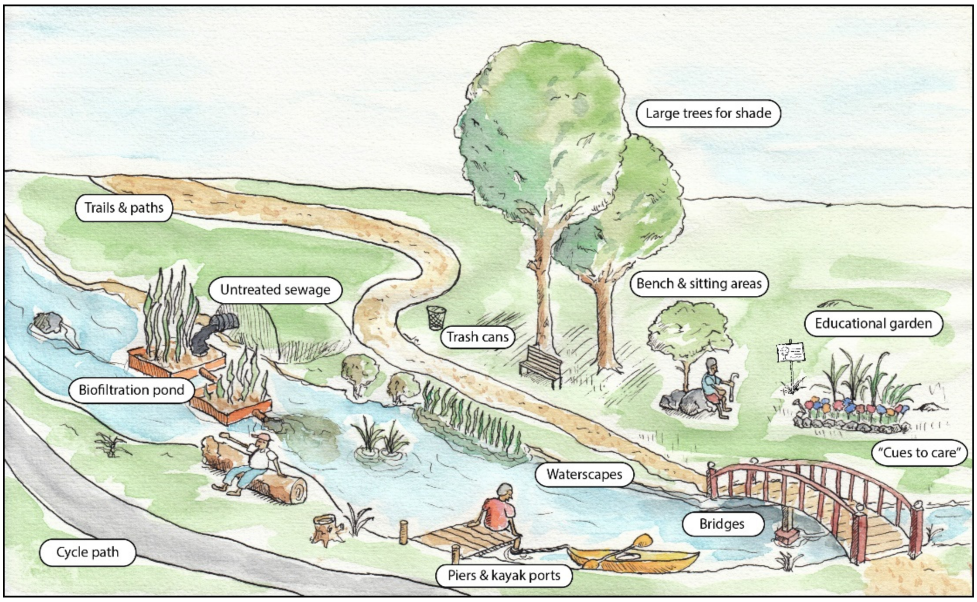

Figure 4. Schematic examples of the actions carried out in the experiences reviewed. The experiences include actions such as creating educational and vegetable gardens, sitting and bench areas, biofiltration ponds, and bridges and kayak ports to create waterscapes where people can access and connect to rivers.

Figure 5. Actions found in two of the Mexican experiences. These are some examples of people´s activities around rivers and their initiatives to rehabilitate or "rescue" rivers in two Mexican cities.

In Xalapa city, neighbor and government organizations worked for several years to rehabilitate the Sedeño River by building trails and paths (top center right) integrated with educational signs (top left) and pedestrian bridges (lower left), among other actions. In the city of Morelia, recreational areas next to rivers were habilitated by neighbors (top right), and agriculture is carried out on the margins of rivers (lower right). Other actions do not necessarily happen next to rivers but are crucial for river health, such as the construction of artificial ponds and wetlands, as in the case of the National Autonomous University of Mexico (UNAM) campus in Morelia (top center left).

3.2.3. Restore Riparian and Aquatic Habitats: Flora, Fauna, and Microorganisms

Restoring riparian and aquatic habitats and the species of flora and fauna that inhabit them has been one of the main objectives of urban river rehabilitation [3,9,39,88]. Agroforestry practices respond to the loss of riparian habitats and the flora and fauna and the failure of the natural pattern of river hydromorphology. The aim is to respond to these problems by generating green riparian zones where citizens plant diverse native plants. The above ensures the effectiveness of the restoration and construct of "cues to care" [89] while inviting people to use these spaces. "Cues to care" refer to the little actions of care of green and public areas, such as the pruning of trees, herbs, and shrubs to make paths more "walkable" and the vista more "visible," to allow for a broader spatial perception of the place, to create the sensation of a site that is being cared for (as in the illustration in Figure 4.

These actions increase river life, for example, the increase in fish species in a stream in Salzburg, Austria (Alterbachsystem). Here, nine species were found after rehabilitation, compared to one species before the stream was restored [11].

Agroforestry as science has generated many studies on native species and local and traditional knowledge that can contribute to ecological restoration and biodiversity. This knowledge can be of great support when selecting the plant species with which to intervene on the riverbanks. Plants not only control erosion [90] but help connect rivers, and this connectivity, in turn, contributes to the mobility of both fauna and flora and serves as a refuge for them [53,91].

3.2.4. Create Local River Cultures and Social Cohesion

An essential aspect of urban river rehabilitation is to enhance a river culture by considering essential social elements such as people´s emotional connection with rivers [17,92]. People need a connection with nature for recreation and leisure [3,88]. The importance of listening to birdsong [92], interactions with other people, and the integration of plants preferred by local inhabitants [3]. To develop projects that integrate both nature and people, "river culture" [38] recognizes the intersection of hydrological, biological, and cultural values, which should be a basis for preserving ecological and cultural diversity along rivers. However, in most of the world's cities, the "river culture" is a culture of spaces that are used as garbage and drainage dumps, areas intentionally rejected and hidden [8,40,41,62,89,92–94]. Integrating "sensory values" [92], such as the presence of flowers or "cues to care," enhance the connection with nature [3,41,62]. It is important to incorporate locally valued plants and elements as a strategy to integrate local cultural expectations of landscapes into rehabilitation strategies [41,62].

The projects included in this study comprise the participation of neighbors in planting and caring for plants (shrubs, grasses) along the riversides, such as in Chapinero, Colombia, where a diverse community, from children to elders, participated actively in transplanting and substituting plants for native species such as *Myrcianthes leucoxyla* (Arrayán) or *Baccharis latifolia* ([95], see p. 193 for other species used). Other experiences, such as Water L.A., integrate people into their "urban acupuncture" strategy to rehabilitate water basins through promoting the construction of "rain tanks, rain grading, parkway retrofits, greywater systems, infiltration trenches, and permeable paving as the six major water management strategies [...]. As part of the process, Water LA also replaces turf grass with native plants and trees and edible gardens" [86,96,97]. All of this is carried out with the active participation of schools, neighbors, and other population sectors. Other practices integrated into different experiences focus on teaching neighbors to compost, environmental education and river cleanup campaigns, building botanical gardens along the riversides, integrating environmental interpretation signs, constructing ecological zones for ecological education and nature education sites, and organizing forums to talk about local rivers.

3.2.5. Guarantee Food Production

Food production receives little attention in the literature on urban river rehabilitation through urban agroforestry, agriculture, and food forestry [98,99]. Despite this, food production in the city is a topic that is beginning to be studied [73–75]. Clark and Nicholas [100] proposed the concept of "urban food forestry." This term articulates agroforestry, urban forestry, agroecology, and permaculture for food production in cities. Urban food forestry contributes to landscapes and minimizes costs using multifunctional species, which produce benefits such as air quality, climate and water regulation, oxygen production, erosion control, and habitat for biodiversity [98,99]. Urban agriculture improves community food security, public health, and social capital and creates microenterprise opportunities [37,101,102]. Despite the importance given to this dimension in the literature, urban rivers are not explored adequately for food production in the literature [100,103].

The Water LA Project "activates Angelenos" to develop edible gardens in their backyards and gardens [86]. They also use gray water and other actions (See Supplementary S1 for reference). In some experiences studied, people implemented programs such as an educational garden and conducted composting efforts in places such as museums [81].

3.2.6. Impact on Public Policies

Worldwide, citizens and politicians have created public policies to restore and rehabilitate rivers, with the rise in Europe (Water Framework Directive [104]) and North America (Clean Water Act and the Urban Waters Federal Partnership [105,106]). For example, in Paris, France, laws were created for factories that discharge substances into water ([107] see Supplementary S1). In addition, authorities encourage farmers not to pollute the river. In the case of the Colorado River, which originates in the United States and whose delta is in the Gulf of California in Mexico, authorities have conducted intersectoral work to generate a binational policy for its management [108]. In Bogotá, the Interlocal Committee of the Salitre River has been working for many years in forums and workshops for a Territorial Environmental Management Plan intending to influence local policies for the management of the Salitre River basin [109].

Zingraff-Hamed et al. [15] reviewed the impact of the European Water Framework Directive on urban river rehabilitation experiences in two European countries. Among the main observations they offer is that arriving at this regional policy requires the consideration of differences in landscape planning approaches and cultural and administrative issues in each country, among other factors. In Germany, for example, priority has been given to recovering the ecological functions of rivers, while France has emphasized social and cultural processes.

3.2.7. Rehabilitate Local Economies and Integrate the Urban Landscape

The rehabilitation of urban rivers represents an opportunity for governments to address the needs of marginalized populations in cities. Marginalized people are in demand not just for services such as running potable water and sanitation [110] but for spaces for recreation, leisure, and connection with nature [61] and, in some cases, to engage in food production systems [111]. Vacant land along riverbanks represents an opportunity to promote the participation of inhabitants in the rehabilitation of their environment and their economy. This is the case for the San Antonio River, where local inhabitants consider that the rehabilitation of the river provided many economic benefits to the population [23]. Some elements integrated into the experiences reviewed were: an equine exhibition area, markets, museums, passive and active recreational areas, sports arenas, and stores.

One controversial issue could be how the renewal of poor and marginalized areas may affect residents in the future, as it may increase the cost of services such as electricity, water, and the land itself. Some projects have included relocating families living along the river bed to other more suitable areas. Still, relocation itself could be considered a sort of displacement of poor inhabitants from the future benefits that the rehabilitation of the river will provide.

3.2.8. Create Recreational Spaces and Contribute to Physical and Mental Health

The need for recreation, a connection to nature, and areas to clear our minds and interact and socialize with other people and non-human beings is of chief importance to human health [112]. The COVID-19 pandemic has increased awareness of the importance that this human-nature connection has for human health [113,114].

Recreation is not only about doing something fun in nature. The emotional relationship between people and nature is also promoted and enhanced through entertainment, and this element can be improved when social values are recognized in rehabilitation projects [41,62]. Users require infrastructure that provides comfort and safety and an aesthetic dimension to the spaces [40]. Water bodies and rivers in cities where people connect with water are of great importance for health [62,114–116], particularly mental health [117].

The rehabilitation projects reviewed here have a recreational and connection-with-nature component. Scholars have suggested that many of these projects include trails and benches [40,62], bike paths [61], bridges [62], and other amenities that enhance the site experience, such as piers or beaches, playgrounds/green schools, public toilets, but also architectural elements inspired on nature, such as vertical terrace walls, as well as willow swamps or marshes and low-lying areas.

Connectivity to other means of transportation through linear and ecological corridors and green riverside areas is also crucial because it allows people to access riverside areas and connect to other green spaces in the city. The vegetation in these strategies is a fundamental element. It is here where the science of Agroforestry can provide solutions that integrate the natural element and the cultural element that rescues local knowledge and preferences about the species that best fit the answers for each situation.

4. Conclusions: The Contributions of Agroforestry to Urban River Rehabilitation Experiences

Lastly, this section discusses how agroforestry contributes to the necessary processes to achieve the goals and social and environmental aspirations of urban river rehabilitation. Agroforestry and its practices offer multiple opportunities to solve problems associated with rivers and the economic, health, and cultural needs of city dwellers. In this sense, it is essential to promote “river cultures” [38] in conjunction with Agri-silvi (cultures) that allow a healthier emotional and spiritual connection with rivers in cities. This connection enables a greater interest in caring for these spaces, their functions, and natural elements and contributes to governance around their conservation [15]. Rehabilitation efforts can create and enhance this culture by changing people’s perceptions of rivers and their biodiversity, including agroforestry [40,64]. It is essential to return to Korsunsky’s argument [70] regarding the need to generate new ecological cultures that allow for different ways of managing ecosystems, for nature to adapt to the conditions of cities, and for those forms of management that are found between “cultivation and desert” [118] to exist.

Currently, urban rivers worldwide are beginning to be seen as connectors between points of interest in the city and as elements for improving neighborhoods [5,61], local environmental improvement, and other benefits. Territorial strategies around urban rivers in recent years have incorporated integrating visions that take into account the functions [41], the hydraulic and ecological aspects, as well as the formal or landscape aspects and, in general, “the elements that allow enhancing the role of rivers in urban and suburban structuring” [19,62].

The state of the rivers in the neighborhoods of the low socioeconomic level of the cities will depend not only on the neighbors' efforts to take care of the river but also on the initiatives that come from the governments, the local business sector, the academic and research institutions, NGOs, and other significant organizations, whose actions have demonstrated the importance of collaboration to empower local riverside cultures and experiences. The experiences outlined in this work are an expression of the potential that rivers acquire when they become the object of local, national, and international initiatives throughout the world; they are also a demand for more significant support from governments and the integration of urban river rehabilitation into public policy [99]. An issue of great importance for the urban development plan will also be solutions to the pressing water problems facing cities worldwide.

Although environmental benefits are the most used justification for rehabilitation projects, it is vital to strengthen the relationship with social criteria so that interventions are accepted, cared for, and promoted by local inhabitants. Studies show the preference of people for mixed-use spaces, that is, spaces that offer recreation, sports, and connection with nature, and that can also become spaces for the production of food or other resources necessary for the population [40,41,62,64].

From an academic perspective, it is imperative to respond to the diversity of socio-ecological needs and aspirations through a strong multidisciplinary understanding [14] of water management in urban contexts. What we find in this review is a variety of cross disciplines, concepts, languages, and conceptual and theoretical frameworks. While there may be different ways of conceptualizing and talking about urban river rehabilitation, the elements and actions are similar in more than one dimension. The rehabilitation of urban rivers must be nourished by the intersection of disciplines, without forgetting that the application of techniques and methods will be based on the specific objectives of each place, the principles that govern the projects, local knowledge and perceptions, and the rehabilitation strategies defined in each case.

We must emphasize that no concept and activity should be considered separately from the others if a rehabilitation project is successful. As we have become accustomed to approaching problems from a disciplinary point of view, it feels out of place to think of integrating efforts to conserve or restore nature with those to improve public spaces, vacant land, or create spaces for recreation. More and more examples worldwide are considering a more integrated perspective for the rehabilitation of urban rivers where agroforestry is an essential element. Agroforestry is one of the fundamental disciplines considered necessary to rehabilitate urban rivers.

Agroforestry is among the fundamental disciplines considered necessary to rehabilitate urban rivers. As our review of concepts and experiences shows, agroforestry intersects and connects concepts with actions and processes, becoming an essential discipline in urban river rehabilitation. Therefore, it is crucial to deepen the systematization of agroforestry knowledge and its contributions to repairing urban rivers.

In the world, more and more city dwellers desire better spaces to connect with nature. Rivers, their beds, and banks offer an excellent opportunity to achieve this desire. What we present here is just a small sample of experiences worldwide where people are working to rehabilitate and connect with their urban rivers in the hope of achieving the social and ecological aspirations of urban river rehabilitation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14137657/s1. Supplementary S1: Experiences in the rehabilitation of urban rivers 17 May 2022; Supplementary S2. Classification of sources reviewed; Supplementary S3. Glossary; Supplementary S4. Map of reviewed experiences in urban river rehabilitation. References [119–196] are cited in the supplementary materials.

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