Aguapuntura: a water-sensitive approach to revitalize informal settlements in the city of Asunción, Paraguay

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Abstract

In the last decades, rapid urban development led to the birth of informal working-class neighbourhoods. This phenomenon refers particularly to big cities of the developing world, where the slum's expansion is uncontrolled and has caused a lack of basic services, drinking water and adequate sanitation facilities, generating open sewers, pollution and landslides due to runoff. The present research, focused on the Chacarita district of Asunción (Paraguay), proposes a multiscalar strategy to manage the water resource, address environmental risk and urban and landscape redevelopment. The study proposes the regeneration of public spaces in one of the sectors that compose the Chacarita Alta neighborhood. The proposed design strategies aim at enhancing its natural and urban heritage through punctual interventions on water involving its collection, purification and reuse. Results underline the potential of the designed prototypes in improving the living conditions of the Chacarita residents.

Il rapido sviluppo urbano nelle grandi città dei paesi in via di sviluppo ha favorito, negli ultimi decenni, la nascita ed espansione di quartieri popolari informali. In tali quartieri, lo sviluppo incontrollato ha causato la mancanza di servizi di base, acqua potabile e strutture igienico-sanitarie adeguate, generando fognature a cielo aperto, inquinamento e smottamenti dovuti al ruscellamento. La presente ricerca, focalizzata nel quartiere Chacarita di Asunción (Paraguay), propone una strategia multi-scalare per gestire la risorsa idrica, affrontare il rischio ambientale e la riqualificazione urbana e paesaggistica dell'area. Lo studio propone la rigenerazione degli spazi pubblici in uno dei settori che compongono il quartiere Chacarita Alta. Le strategie progettuali proposte mirano alla valorizzazione del suo patrimonio naturale e urbano attraverso interventi puntuali sull'acqua che ne prevedono la raccolta, depurazione e il suo riutilizzo. I risultati sottolineano il potenziale dei prototipi progettati nel migliorare le condizioni di vita dei *chacariteños*.

Keywords

Informal urbanism, Water purification, Green and blue infrastructure, Environmental risk, Water resource management.

Urbanismo informale, depurazione dell'acqua, infrastrutture verdi e blu, rischio ambientale, gestione della risorsa idrica.

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Informal settlements: water, landscape and main features

In the last few decades, it has been observed an important demographic growth, which has led, in most cases, to uncontrolled urban expansions without adequate planning (United Nations Human Settlements Programme, 2007). There are now 7 billion people on the planet, and global agencies are projecting continued population growth. Most of this growth, however, will not be in the developed world. By 2030, there will be 7 billion people in the developing world alone and only 1 billion in the developed world. Already, over 30 percent of the world's population live in informal housing settlements otherwise known as slums, barrios or favelas (Taylor, 2011). Latin America is considered the most urbanized and unequal region in the world; 80 per cent of its population lives in cities, and more than 111 million people live in squatter settlements. All countries that constitute Latin America are developing countries; approximately 124 million of Latin American urban inhabitants live in poverty. The south continent has always been characterized by the concentration of population in a few cities. However, nowadays the megacities of the subcontinent (Sao Paulo, Mexico City, Buenos Aires, among others) concentrate only 14 per cent of the urban population; while more than a half of urban inhabitants live in "secondary metropolis" (Maldonado, 2014).

Within these megacities informal settlements are home to more than a billion people who suffer from poor health and wellbeing as a result of inadequate water and sanitation services, and environmental exposure to pathogens, pollutants and disease vectors (ADB and RISE, 2021). A review of the definitions used by national and local governments, institutions involved in slum issues and public perceptions reveals these attributes of slums:

- lack of basic services;
- illegal and inadequate building structures;
- overcrowding and high density;
- unhealthy living conditions and hazardous locations;
- irregular or informal settlements;
- poverty and social exclusion (United Nations Human Settlements Programme, 2007).

In recent years, prevailing strategies for addressing informal settlements have moved away from large-scale slum clearance and relocation. The approach favored today involves on-site upgrading and improvement, with the goal of integrating low-income communities into their larger urban contexts. [..] That said, however, there is no clear set of best practices for these upgrades, which span from small, acupunctural insertions to expansive infrastruc-

Fig. 1 – Overview of the area called 'La Chacarita'. (Image from. Benítez A., Pérez C. 2017, *La pasión en la "Chaco"*, in *La Nación*, <https://www.lanacion.com.py/reportaje/2017/11/14/la-pasion-en-la-chaca/>).

tural improvements; from family-based, government-led programs to designer-supported projects (Werthmann, 2022, p.2).

Open water is, in most informal neighborhoods, an unattractive, even threatening element. Informal urbanization typically faces away from creeks and rivers for good reasons. Many informal neighborhoods of Latin America are located in tropical and subtropical climates characterized by periods of heavy rainfall. Many settlements are prone to flooding, since the impermeability of previously open terrain can reach up to 90% and has increased runoff tremendously. [...] In general, there is an overabundance of polluted water, whereas clean water can be scarce (Werthmann, 2022, p.23).

Environmental pollution caused by the lack of services and wastewater collection systems affects the health of those people living in uncontrolled settlements. For these reasons, replace and rearrange the existing informal plots as well as organize a wastewater collection system, represents a significant challenge. In this kind of context, the principles of conventional engineering cannot be applied and it is not possible to comply with the codes and regulations envisaged for formal cities, as they are impossible to adapt to the informal context without representing a prohibitive cost (Franco, 2014).

The research aims to consider water as a resource and not as a threat, improving the sanitary conditions of an informal district, enhancing and preserving the green and blue areas, reducing the environmental risk and providing drinking water to the inhabitants. The project will be focused in the present and potential public spaces of the area, following

Fig. 2 – La Chacarita: framing and environmental issues (Elaboration by the authors based on Rossignoli, L. (2022) with data retrieved from: Cabrera A., Congo J. 2019, *Estudio de diagnostico Chacarita Alta,* Ministero de Urbanismo, Vivienda y Habitat, Asunción).

the approach of urban acupuncture, with the aim of enhancing the present landscape and cultural heritage and encourage the meeting among its residents.

La Chacarita: an identity and problematic neighborhood in Asunción, Paraguay

Among the sixty-eight neighborhoods that make up the city of Asunción, the research focuses on the Ricardo Brugada neighborhood, analyzing it with a multi-scale approach. With approximately 13,037 inhabitants, the density of the neighborhood is three times the average density of Asunción. In this area the inhabitants are poorer but also younger than the rest of the city. It is a strategic area located between the Banco San Miguel ecological reserve and the historic center of Asunción. It extends for about 150 hectares and completely includes the area popularly known as "La Chacarita", shown in figure 1.

The Chacarita neighborhood consists of two well-defined areas:

- the upper area, also known as 'Chacarita Alta', located towards the formal city, develops on a topography with variable slopes and ravines of over 10 meters. This is the oldest and most consolidated area. It includes about 836 homes for a total of 3,147 inhabitants;
- the lower area, also known as 'Chacarita Baja', located towards the bay of Asunción and the Paraguay river, forms part of the alluvial plain of the river, and for this reason the occupying population is the one most affected by the periodic flooding of the watercourse. In this area live 1,841 families, for a total of 6,724 inhabitants (fig. 2).

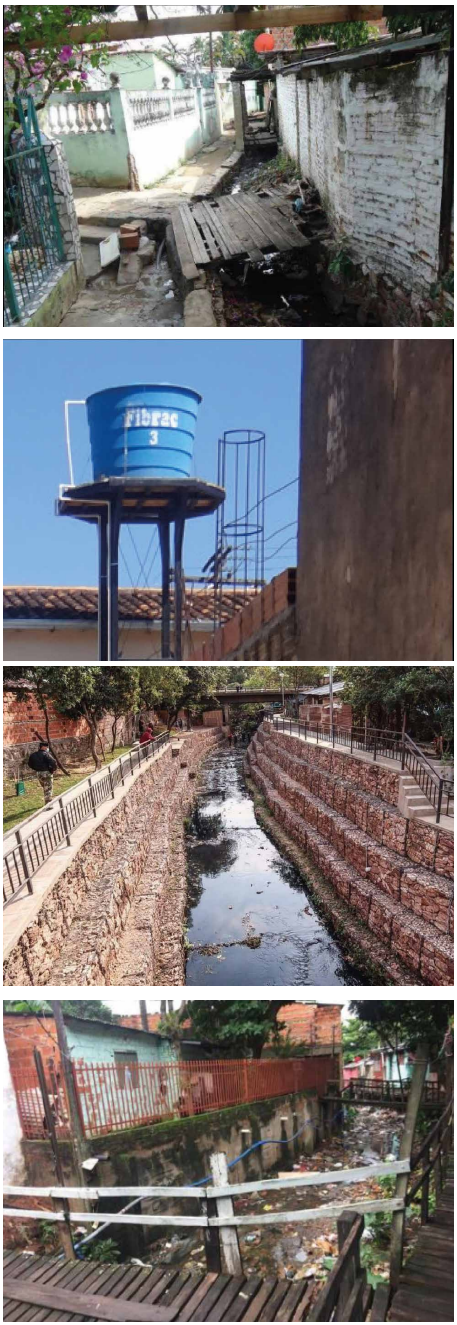

Fig. 3 – Water shapes in the study area: threats and opportunities. Imagines from: Ministero de Urbanismo, Vivienda y Habitat. 2019, *Estudio de impacto ambiental preliminar: Mejoramiento Integral del Barrio Chacarita Alta,* <https://www.mades.gov.py/wp-content/uploads/2019/10/5116_tecnoambiental.pdf> (01/23).

Although the limit between the two zones is a physical limit represented by the safety altitude of the city (64 m asl) from river flooding, residents use Florencio Villamayor street as an imaginary boundary. Given the proximity to the Paraguay River, the course of the streams in the area follows the slope of the land up to the river, channelling the rainwater and depositing sediments and solid urban waste in the lower area of the city, up to the bay of Asunción. In the study area there is no planned system for the collection and disposal of rainwater, which follows the natural path of the slope. Surface runoff causes ravines which in some cases are more than ten meters high, near the streams of the neighborhood (Mexico, Tacuari, Anteqeuera), posing a threat to housing in this area. Furthermore, Chacarita was not affected by the change of urban reform of 1821. As a result, there is no adequate infrastructure and the district does not have a homogenous sewage system. Currently, the sewage system depends on the possibilities that each house finds: the residues are discharged into the open air channels and into the beds of streams, causing strong smells throughout the neighborhood, as well as highly unhealthy conditions. The streams constitute real open sewers bringing with them factors such as marginality, delinquency, water-related diseases and a fertile ground for the proliferation of dengue (Cabrera & Congo, 2019). In figure 3 it is possible to observe the relationship between the district and the water: most of the population lives near this resource but cannot access it.

Chacarita Alta: risk and heritage

The research focuses on the upstream area of the district, which is more consolidated, with the aim of intercepting and purifying upstream rainwater and wastewater that contribute to the flow in the lower area of the Chacarita and in the bay of Asunción, polluting it. Chacarita Alta is an informal neighborhood that has developed following the slope of the

land and the bed of the existing waterways (Mexico, Antequera and Tacuari). It is one of the oldest districts of the city, whose history is linked to the growth of the Paraguay River, the old subsistence crop farms and the fishermen of the Asunción Bay (Cabrera & Congo, 2019). The district has territorial subdivisions made by its inhabitants, whose limits are both anthropic, such as roads, bridges and alleys, and natural, due to the morphological development of the territory and the presence of the streams. The headquarters of the football clubs present, *03 de Febrero*, *Oriental* and *Resistencia* generate the main subdivisions within which the inhabitants declare to belong. In addition to the separation of the area from the sports clubs, the Chacarita Alta district contains other subdivisions by sectors that have formed gradually, for a total of eighteen sectors.

Each sector has been studied and analyzed considering four levels:

- risk: represents the houses which declare to be in danger of flooding, due to the periodic flooding of the river Paraguay and in danger of landslide, due to the erosion that the natural watercourses generate along their banks, or both;
- weak network: map dwellings that claim to be connected to a district sewerage system, which discharges into stream water without any treatment; dwellings that discharge their waste into ditches, blind wells or directly in waterways or houses that instead declare not to own even a bath;
- natural heritage: indicates the main green and blue areas within the Chacarita Alta district. The blue heritage is represented by the streams Mexico, Antequera and Tacuari; the green heritage, however, is mainly characterized by the large trees present in the interstitial spaces between the different houses and along the natural waterways;
- built heritage: shows the main points of interest landscape, cultural, social and identity that develop along the road network consisting of main roads and a network of pedestrian alleys.

The overlapping of these levels draws up a map of the environmental risk, depending on the hydrogeological risk, the risk linked to possible flooding of the river Paraguay, the presence or not of a sewerage system, the density of houses and the amount of existing vegetation. The maps illustrated in figure 4 show that the areas near the streams are in a greater environmental risk, polluted by the discharge of waste that occurs without treatment. Furthermore, the torrential motion of the water increases the risk of landslides along the stream banks. Into Chacarita Alta district, the sanitary and environmental conditions are different, depending on the geographical location of each sector.

In this district there are a lot of communities, which shape social relations and the permanent and casual meeting between the inhabitants. This represents a strong point for the area: this way of life makes the neighborhood unique and owner of a strong identity and a great sense of belonging to its own spaces, although it does not have the minimum equipment or basic infrastructure (Cabrera & Congo, 2019). As it is shown in the fifth figure, the public spaces in the neighborhood can be divided into three different typologies:

- main and secondary road network: carriageable streets and pedestrian alleys that wind through the different sectors of the Chacarita Alta. Within this network there are the main points of social, cultural and panoramic interest and the projects of the XI BIAU;
- green areas between the houses: covered with large trees, represent an interesting potential for the reuse of space. These are the few permeable areas exi sting between the buildings;
- green areas along the streams: along the streams Antequera, Mexico and Tacuari is concentrated most of the vegetation, which is bumpy and not enough to ensure adequate stability on the slopes.

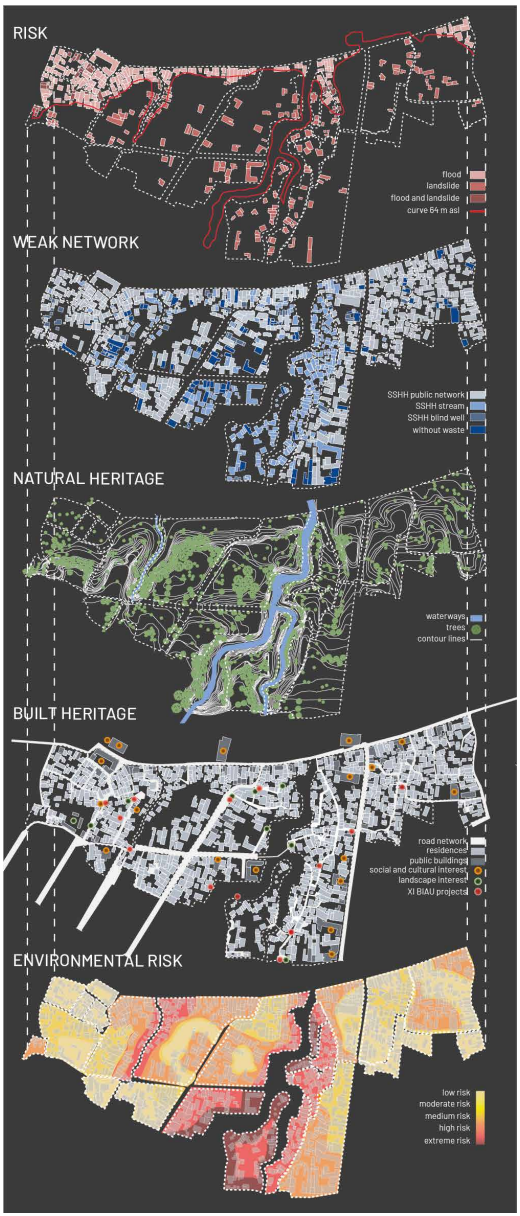

Fig. 4 – Chacarita Alta: four levels of study and environmental risk. Elaboration by the authors based on Rossignoli, L. (2022).

The analysis of the study area with all its criticalities and potentialities represent a fundamental step for the design strategies detailed below and focused on the footprint of public space. All the proposed actions are aimed at improving the sanitary conditions of the neighborhood, reducing environmental risk, providing drinking water to its inhabitants, improving social inclusion and enhancing the environmental, social and cultural landmarks already present in the district.

Sector F Minisantos: analysis and strategy adopted

From the analysis of the hydrogeological risk, the existent drainage network, the natural and built heritage it is clear that the sector F reflects most of the existing situations in the Chacarita Alta district, both in terms of current environmental hazard and as a public area available for intervention. As a result, this area was selected as project site. Following the principle of urban acupuncture (Lerner, 2003), the adopted strategy is based on punctual and widespread interventions of social and environmental interest, on the ground and on the existing road network, respecting criteria of adaptability and compatibility to the site. The strategy (fig. 6) focuses on the water cycle and consists of three main phases:

- first phase: collection and storage of rainwater;
- second phase: purification and reuse of rainwater;
- third phase: reuse or expulsion of wastewater and meteoric water.

The design strategy highlights the possibility to collect rainwater in different ways (through both cisterns or tanks or a detention pond), purify and reuse it for domestic and agricultural purposes. The runoff associated with both rainwater and wastewater is assumed to follow the topography of the ground (i.e. water flow by gravity). Consequently, the associated flows are intercepted, treated and reused

Fig. 5 – Chacarita Alta: current and potential public space. Elaboration by the authors based on Rossignoli, L. (2022).

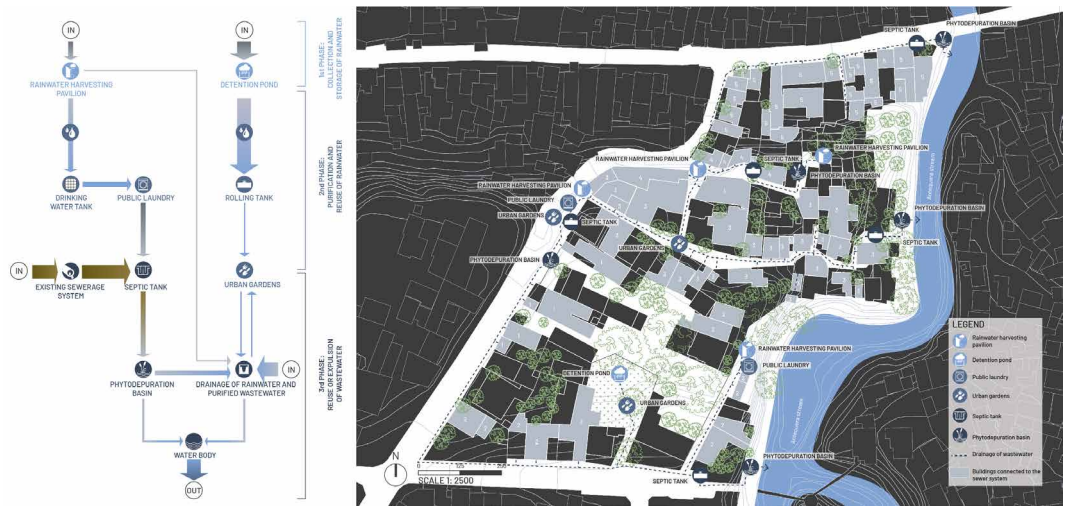

Fig. 6 – Sector F: hydraulic design strategy. Elaboration by the authors based on Rossignoli, L. (2022).

Fig. 7 – Sector F: masterplan. Elaboration by the authors based on Rossignoli, L. (2022).

in specific points in the public area before being released into the Antequera stream.

Collection, purification and reuse of water resources in sector F

In the Minisantos sector, it is proposed the complete rebuild of the pedestrian sidewalk, using the brick, a local and colored material. As underlined in figure 7, the road highlights the path that wastewater follows in the area, connecting the various public places of interest.

1. Network of *pasillos*. The alleys (*pasillos*) of the sector are the main access routes to the houses of the area, where the daily life of the inhabitants takes place. Today, however, they are in a precarious condition, becoming rainwater drains during significant weather events. For this reason, the research proposes the revitalization of the pedestrian streets, through the complete reconstruction of the pavement and the implementation of a rainwater drainage channel, reducing the surface outflow. Within this network, there are some spaces of landscape interest that enjoy an amazing view of the bay of Asunción to the north and the stream Antequera to the east. In these strategic areas the project proposes the construction of four pavilions, made with local and cheap materials (timber and polycarbonate). The pavilion's structure follows the module of a 1000 l water tank (1000 x 1200 x 1000 cm) and allows the collection, depuration, storage and reuse of a certain amount of rainwater (the different pavilions collect 1630 and 4220 liters each month). The objective of this pilot project is to

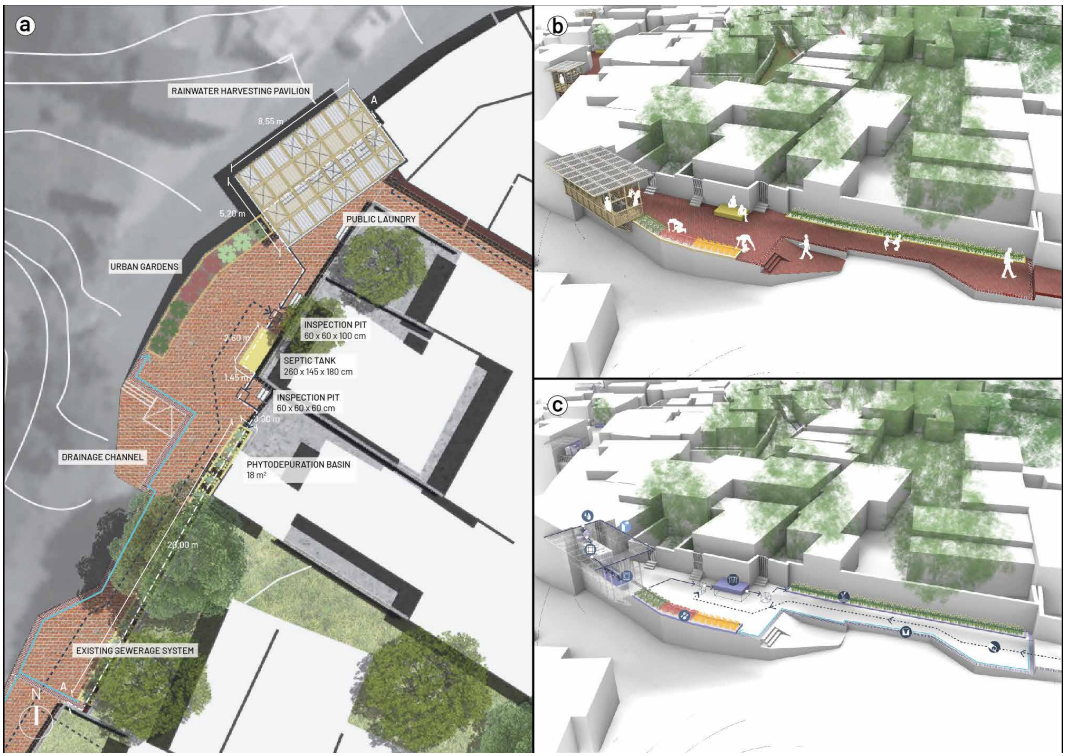

Fig. 8 – Sector F, first focus: Mirador Paraguari. Masterplan (a), view of the project (b) and the connected water cycle (c). Elaboration by the authors based on Rossignoli, L. (2022).

show the opportunities offered by a stormwater collection system in an area where the percentage of drinking water is low. The inhabitants will be able to use these systems for drinking, cooking and other domestic activities. Moreover, in the network of pedestrian walkways, it was designed the system of treatment and purification of the existing wastewater and grey water generated by the new public laundries, using septic tanks and phytodepuration basins. These systems do not hinder the passage and access to individual homes, favoring new possible seats for the inhabitants. The purified water can be reused for urban gardens and agricultural activities along the road, through the drainage channel that allows the functioning of this water cycle (see details in figure 8).

2. Green area between the houses. The second intervention is located in the central green area, bordered to the north by a wall that divides the lots of different houses. Within this sloping area, the research proposes the design of a detention pond, to facilitate the collection, treat and reuse of rainwater and create a space for social interaction, a playground where people can play, have fun and recreate themselves. The material used to build the reservoir is porous concrete, a permeable surface where various activities can be performed: basketball, *joca pelota* and squash. During a rainstorm, the water will be channelled into the centre of the soil and then stored in a rolling basin under the ground as shown in figure 9. The rolling basin is characterized by a volume of 10,5 m^3, considering that the tank must be sized

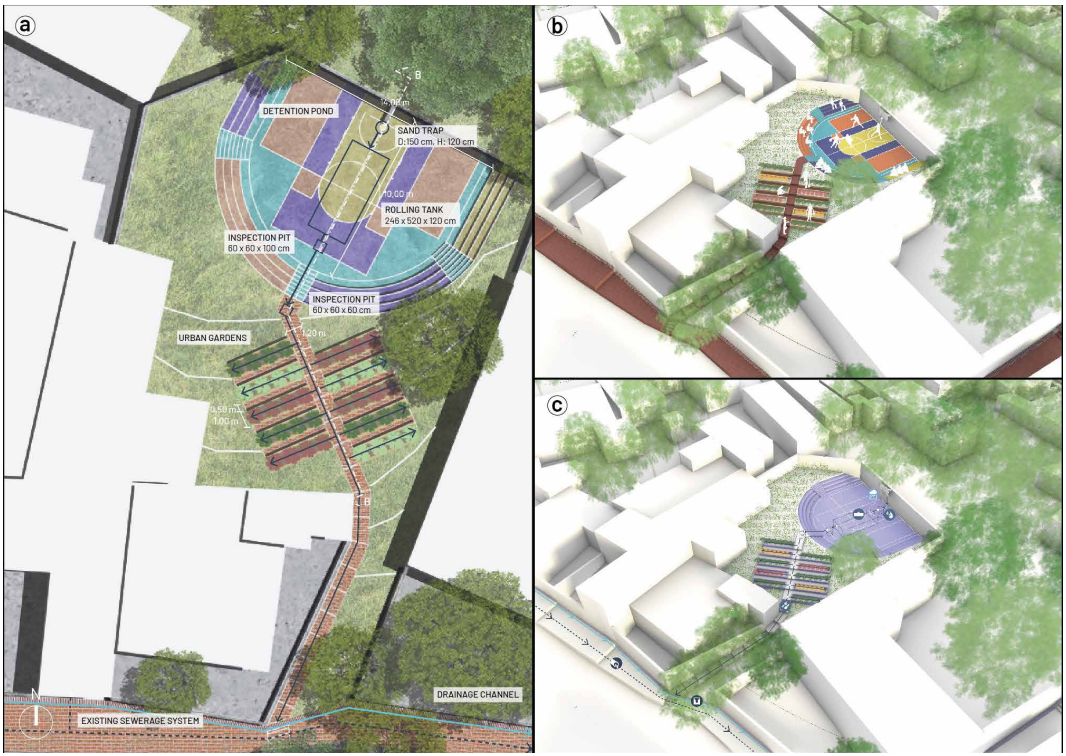

Fig. 9 – Sector F, second focus: the green area between the houses. Masterplan (a), view of the project (b) and the connected water cycle (c). Elaboration by the authors based on Rossignoli, L. (2022).

to contain the rainfall rate of an hour, taking into account a return period of 50 years. The rainwater stored can be pumped to irrigate the vegetables gardens, through a system of sub-drip irrigation. In this area, water is stored and reused for agricultural purposes, promoting social inclusion between the inhabitants and producing healthy food for the poor population.

3. Antequera stream. The objectives of this intervention are to improve the quality of Antequera stream, to purify the wastewater before dumping it into the water body, to enhance biodiversity planting shrubs and trees and to improve the accessibility and the north-south permeability of the sector. As shown in figure 10, two terraced systems were designed using stone gabions and covered with a continuous brick pavement. In these areas, septic tanks and phytodepuration basins made of prefabricated concrete allow the treatment and disposal by gravity of wastewater from homes that declare to be connected to a sewerage system. Along the riverside, the recent consolidation of the banks made by the municipality of Asunción is used to create a linear path, improving the accessibility and the interaction between nature and the informal neighborhood. The new riparian buffer is a simple and economical way to protect and improve water quality and decrease pollution, reducing the risk of erosion and possible collapses. The plants used are perennial grasses, which slow the runoff and absorb most of the pollutants, and native plants.

Fig. 10 – Sector F, third focus: the area along the Antequera stream. Masterplan (a), view of the project (b) and the connected water cycle (c). Elaboration by the authors based on Rossignoli, L. (2022).

In Sector F the following results are observed:

- the four rainwater harvesting pavilions collect 12,000 L of water monthly (taking into account the average monthly rainfall of Asunciòn and the catchment area). This resource can be used for drinking and cooking for 67 inhabitants, about 1/3 of the resident population;
- the rolling tank below the detention pond in the green area has been sized to store up to 10,500 L, taking into account the rainfall curves of the capital and verifying the water requirements of the new urban gardens;
- the five wastewater purification systems, located along the pedestrian streets and on the edge of the Antequera stream, allow to treat 56.8% of the waste water produced in the area, for buildings that claim to be connected to a network;
- the revegetation of the stream edge reduces the risk of landslide for homes that are located near the watercourse and filters between 50 and 85% of the pollutant loads contained in rainwater, according to Huber (2010).

Finally, the proposed interventions follow criteria of suitability to the site, without altering the conformation of a strongly consolidated sector, enhancing the areas that have a recreational and landscape potential, in order to improve the living conditions and health of its inhabitants. Special attention was paid to the cost-effectiveness of the proposed interventions, which are adapted to the scarce economic resources present in the district of Chacarita.

Conclusions

The proposed research focuses again on the scale of context, after explaining, sizing and highlighting the project for a sector focus, in order to show the potential of a strategy that is adaptable and transferable to other sectors of Chacarita, with a view to reducing pollution, improving hygiene conditions, enhancing biodiversity, promoting social inclusion and make the intervention unified. The project suggests to increase the number of systems proposed in Sector F, in order to obtain a greater benefit on a large scale, in particular:

- add 32 rainwater harvesting pavilions: whereas the required daily water requirement for drinking and cooking is 6 litres/person, these systems are able to cover about 12% of the needs of the Chacarita Alta and 6% of the Chacarita Baja. These structures may be located at identified points of social and landscape interest. In Chacarita Baja, due to frequent flooding, these prototypes could arise on stilts, as to be always efficient during the year;
- regenerate 6 internal green areas: in these areas it is proposed to design reservoirs for storing rainwater, in order to retain this resource and reuse it for agricultural purposes;
- purify wastewater from buildings connected to a network: for Chacarita Alta buildings connected to a sewerage system (62,7% of the total) it is proposed to intercept the existing network at certain points in order to purify and reuse the wastewater produced by the inhabitants. It is proposed to implement 60 purification systems, consisting of a primary (tricameral septic tanks) and secondary treatment (phytodepuration systems).

The proposed interventions are prototypes to improve the living conditions of Chacarita residents. The pavilions are temporary structures, which want to provide drinking water to the *chacariteños* and do not satisfy the entire daily needs required by the population, which according to the WHO (World Health Organization) must be at least 50 litres/inhabitant to ensure an acceptable living condition. For this reason, it is necessary to intervene in private and implement rainwater harvesting systems to individual homes. Also for wastewater it will necessary to intervene in private, since currently only 62.65% of buildings are connected to a drainage network. These interventions will be located within the Chacarita Alta district, as it is consolidated and not affected by the flooding of the river Paraguay. Downstream, however, these interventions would be ineffective, since the area is constantly modified from the periodic floods of the river. In the Chacarita Baja district it will be necessary to solve the problem of floods, which may be the subject of future studies.

The research highlights how in informal neighborhoods there is a water heritage to be preserved and enhanced, which can appear in several shapes. Water, which is often seen in these contexts as a threat, an unattractive element that brings with it degradation, hydrogeological problems and disease, can become an opportunity to regenerate public space. Following a bottom-up approach, involving the resident population, which takes into account the fragility and the existing heritage, and according to the principle of urban acupuncture, water becomes a promoter of social, urban and environmental regeneration.

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