The River and the Mosaic: Regenerative Cycles in Production Landscapes

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01. Drought

01.01 Introduction

The starting point of this thesis probably was the study trip we did with the Honours Programme group in August 2022. Four other students and I were researching the Paraná River delta within the framework of the Delta Futures Lab under the coordination of Dr Fransje Hooimeijer and Dr Luca Iuorio. Together with students and professors from the Masters of Civil Engineering and Water Management, we planned a study trip to Buenos Aires, which is near the delta, where we were warmly welcomed by professors of the Universidad de Buenos Aires and the researcher Veronica Zagares. We had quite a busy schedule of visits and lectures, which gave us a general overview of the numerous issues revolving around the deltaic system. By then, I was almost sure I would continue working with that location as my graduation project because one of the issues instigated me: was the fact that every year, the shoreline advances around 100 metres due to sedimentation processes. That meant yearly 100 metres of new land, new islands, expanded ecosystems, and a handful of ownership and planning issues to be tackled.

Back in Delft, in September 2022, we started working with Prof. Dr Steffen Nijhuis at the Resilient Coastal Landscapes graduation laboratory. My fascination with the growing delta was the main reason I chose this laboratory in the first place. However, as research on the topic went on, I started to realise that a significant part of the threats to a healthy deltaic system was connected to a severe ongoing drought event, which was evoked many times during our stay in Buenos Aires but that somehow remained in the background of our work. Thus, looking into drought became the primary framework for my research. Indeed, it is the worst drought event on record in the last 77 years. Indeed, it is causing marshlands to dry along the Paraná River, which entails ecosystem loss and fires, which we witnessed when visiting the delta. Moreover, the decreased flow of freshwater into the Atlantic Sea is facilitating its tides to penetrate the continent, increasing salt intrusion in-ground and above-ground freshwater systems. Such is harmful not only to local ecosystems but also to human uses of the land, as in agriculture and forestry production

The dramatic consequences of the drought event were clear and easy to spot - even though photojournalists such as Sebástian Lopez Brachs help us grasp the severity and beyond-human scale of climatic events like

Location of the Paraná River Basin in South America.

this[01]. On the other hand, the causes of the drought are still contentious among the scientific community, which acknowledges the interplay between anthropogenic climate change and changes in land use (Rafee et al., 2022; Lee et al., 2017) but could not reach a consensus on what is the leading player in this regard. This entailed a personal challenge of positioning myself as an aspiring Landscape Architect, which differs from a Climatologist, a policymaker, or an Agronomist. I clearly cannot understand our new climatic regime, let alone propose ideas to change or "correct" it. However, scholars who could do much better than I refer to changes in land use as one of the causes of the drought event, and this sits within the scope of action of spatial design.

As research on the functioning of the Paraná River Basin (PRB) system advanced, I found myself back in my home country. The Upper Paraná River Basin (UPRB) is arguably responsible for regulating hydrological flows in the whole PRB because it receives the most significant share of all the rainfall in the system. Situated virtually entirely in Brazil, it is one of the country's main economic engines. This fact, combined with personal familiarity with the culture, the language, and the local dynamics, led to the decision to take the UPRB as the geographic frame for research.

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01 https://elpais.com/internacional/2021-08-01/rio-adentro.html

Fig 01. Fire in the delta region, around the city of Zarate, Argentina. August 2022.

Fig. 02. Photojournalist Sebastian Lopez Brachs reporting for El Pais.

01.02 Systematic tensions

The Paraná River Basin is a landscape of massive figures and dimensions. Metcalfe and Menone (2020) highlight its titles: the second largest drainage basin in South America (second only to the Amazon River) and the 13th largest freshwater system on the planet. Most of the basin is under two climates (Tropical and Subtropical) and has at least seven different ecosystems[01], putting it among the Biodiversity Hotspots of the World[02].

The UPRB, which is the focus of this research, can be geographically defined from the Paranaiba River's source to the Paraná River's confluence with the Paraguay River. It is around 3.480 km in length. This basin was once almost entirely occupied by the Atlantic Forest and the Cerrado biomes. Regarding comparison, the Atlantic Forest is believed to have been as rich in biodiversity as the Amazon Rainforest (Morelatto, 2000). It is also the most abundant area in terms of rainfall, to the extent that Drago and Amsler (1998) affirm that this part of the basin regulates the hydrologic regime of the rest of the system. Measuring stations located at the confluence of the Paraguay and Paraná rivers indicated that the latter contributed 80% to the total discharge at that point (Meis & Llano, 2019; cited in Metcalfe et al., 2020).

The river also runs underground. Several aquifers compose the Paraná River Basin, the Guaraní Aquifer being the biggest. It spreads across Argentina, Brazil, Paraguay and Uruguay and comprises porous sandstone and impervious basalt rock.

In the 20th century, the basin began to be settled intensively. In the upper part, the construction of hydroelectric dams from 1960 to 1990, which provided cheap electricity, laid the foundations for rapid urbanisation, new industrial plants and intensive agricultural production. The construction of the Itaipu Dam in 1984, at the border between Argentina, Brazil, and Paraguay, can be seen as a milestone since it is the second-largest hydroelectric power plant in the world. In the lower areas, the meat production industry

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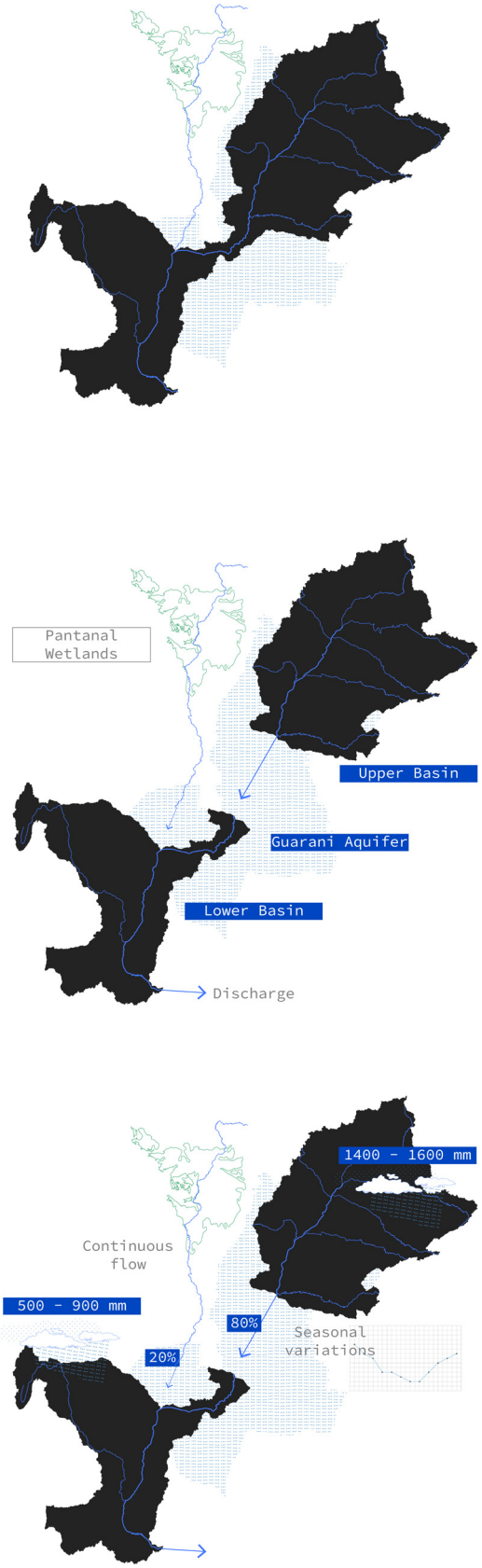
01 https://ecoregions.appspot.com/

02 https://atlas-for-the-end-of-the-world.com/world_maps/world_maps_biological_hotspots.html



Diagrams analysing how the system functions in different parts with different roles.

was the primary shaper of the landscape. As a result, nowadays, the whole of the PRB is home to around 100 million people - which corresponds to 42% of the total population of the four countries combined - and to the most industrialised areas in South America (Metcalfe et al., 2020). Of these 100 million people, around 67 million live in the UPRB[03]. Moreover, land use in this area reflects how the economy and culture of Brazil, Argentina and Paraguay are deeply tied to agricultural production, currently especially to the so-called cash crops, which stand for commodities (such as soybeans, corn, sugar cane, and coffee) produced mainly as exports. As of 2023, Brazil is the global leading producer of soybeans, coffee, sugar cane, orange juice, meat and tobacco[04].

The coexistence, within the same watershed, of all the characteristics mentioned above can quickly escalate into significant tensions, maybe scratching the surface of the underlying complexity of this landscape. It is acknowledged that agribusiness led to skyrocketing deforestation between 1950 and 1990 and consequent soil erosion. P.C. Rocha et al. (2020) describe local agriculture as highly mechanised and intrusive on hydrological systems as it destroys riparian forests and occupies the edges of watercourses. Practices generally consist of annual crops, which entail high levels of soil erosion after harvest season - up to 15 tonnes of topsoil per 1000 sqm are annually eroded and contribute to the silting up of rivers (GeoBrasil, 2007). In parallel, agricultural practices from 1970 onwards made intensive use of fertilisers, pesticides, and agrochemicals. Both factors contribute to water eutrophication, causing a drastic decrease in water quality and putting native fish on lists of endangered species.

The building of hydroelectric dams made water more readily available for agribusiness throughout the whole year, smoothing the yearly seasonal fluctuations proper to the Paraná River system. In Brazil, the upper stretch of the Paraná River was transformed into a series of reservoirs. However, as Shah and Kumar (2008) point out, as dams turn flowing water

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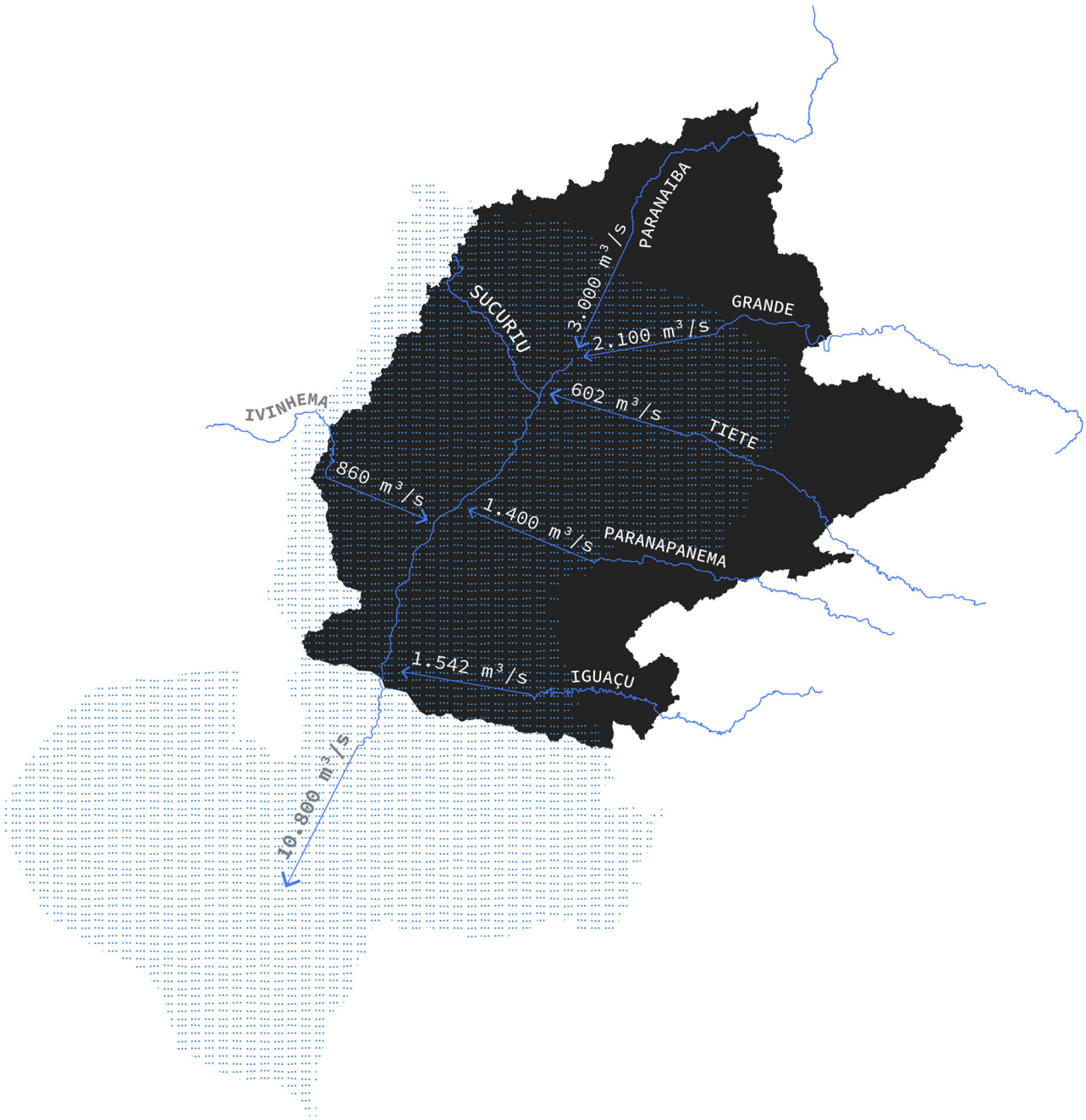
03 Estimated by the author based on data retrieved on Lehner, B., Grill G. (2013). Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186.

04 https://atlas.cid.harvard.edu/



Main tributaries of the Paraná River in the Upper Basin.

into still 'lakes', they affect ecosystems that depend on such flows. They flood areas previously occupied by riverine corridors and marshlands and dry areas previously seasonally flooded. Variations in water levels are now artificially controlled. They change sedimentation patterns, contributing to water eutrophication (Tundisi, 2016), and disturb riverine cultures and traditional human bonds with rivers, such as small-scale fishery.

Finally, the increasingly great water demand from the 67 million inhabitants, intensive agricultural production, and industries puts even more pressure on the system, as drought events also entail drastic human and economic damage.

Uncertainty about the developments of anthropogenic climate change in the region calls for more resilience-oriented actions to prevent socio-economic and ecological losses. An extensively accepted global climate change hypothesis is an increase of 1.5°C by the end of this century, which profoundly affects precipitation patterns everywhere (Flato et al., 2013). In South America, latitudes between 5 and 20 degrees south are expected to experience reduced rainfall (Chou et al., 2012).

Collischonn et al. (2020) compared 25 different Global Climate Models from different institutions and discussed the consensual trends that could be identified. They stress an expected reduction in discharge up to 30% in the rivers at the Upper Paraná River Basin and highlight the fact that such a parameter is a combination of changes in rainfall, evapotranspiration and water balance. This trend is consistent with the expected rise in aridity in the region, represented by the Aridity Index (AI) and consisting of the ratio between Potential Evaporation and Precipitation in a region.

As Charles Darwin noted, during his expedition, Voyage of the Beagle in 1833, local people around the Paraná River in Argentina and Uruguay mentioned periods of 10 to 15 years of droughts or floods. The Paraná River Basin might be a landscape of striking variabilities (Barros et al., 2006), but, at the same time, a widely accepted fact about anthropogenic climate change states an amplified magnitude and frequency of extreme events, such as flood or drought. In this line of reasoning, the Paraná River Basin is expected to experience an amplification of its initial variability, but now with less resilient forms of land use, millions of inhabitants and a robust economy consuming its resources.

The drought event of 2019, which was one of the earliest triggers for this research, exacerbated tensions and made frailties explicit. The higher the ecological richness, the higher the environmental losses that come with

extreme events. Likewise, the bigger the economy, the bigger the losses. So far, developments have happened in contradictory ways: Deforestation increases agricultural production but decreases habitat for endangered species. Hydroelectric dams increase water availability for agriculture and industries but make riverine systems disappear and deregulate seasonal processes. Can development happen without such contradictions? How can the Upper Paraná River Basin be planned more resiliently to contribute to a healthier whole Paraná River Basin? The earliest aim of this thesis is to regenerate the disrupted hydrological cycle to restructure the Paraná River as a corridor for coupled biodiversity and human development.

01.03 The 2019 drought event

The drought event started in mid-2019 with below-average precipitation in the Upper Paraná River Basin, reaching the lowest values on record. It is regarded as a cumulative precipitation anomaly happening since 2016 (Naumann et al., 2021). The duration of the event quickly and steadily led to the disruption of the hydrological cycle, which then led to the geographical expansion of the event. The Intergovernmental Panel on Climate Change (IPCC) proposes three types of drought: meteorological, agricultural/ecological, and hydrological.

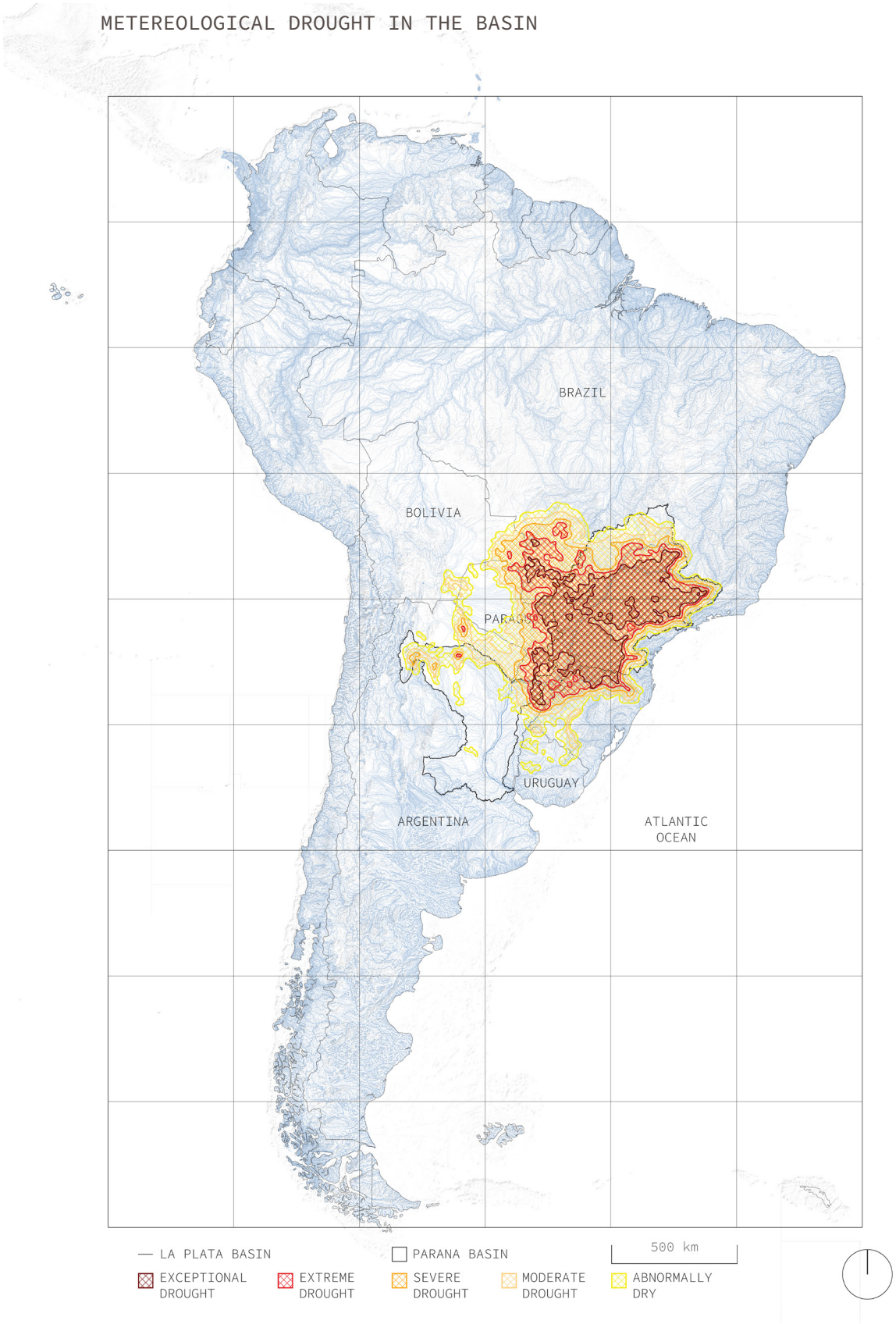
Meteorological droughts consist of periods from months to years of low precipitations, frequently associated with higher temperatures and dryer soils. They are usually the trigger for the other types of drought. Agricultural or ecological drought corresponds to the lack of moisture in the soil, which leads to loss of vegetation, habitat and wildfires, as witnessed during the trip to the Paraná River Delta in 2022. Hydrological drought stands for the falling levels in rivers, reservoirs and lakes in a system and is usually the last to manifest since there are usually water storages that continue to feed the system for a while, such as aquifers.

The spatiotemporal evolution of this drought event reached the Argentinean pampas at the end of 2020, where the three types of drought mentioned above could be observed. Ecological drought manifested through drying marshlands, causing ecosystem loss and facilitating the extension of fires. The hydrological drought could be seen in significantly reduced discharges: according to the Argentine “Instituto Nacional del Agua” (National Water Institute), the Paraná flow into the deltaic region was less than half the historical 25-year average.

However, when discussing the causes behind the drought, there is less consensus within the scientific community. From a brief literature review (Naumann et al., 2021; Rafee et al., 2022; Lee et al., 2018), there are several factors that consensually contribute to the hydrological anomalies in the region: anthropogenic climate change; changes in land use and occupation; and wide scale climatic phenomena, such as the Pacific Decadal Oscillation or the El Niño/La Niña, known for causing flood and drought in some South American countries. The lack of agreement lies in the extent of each factor’s role in this specific event.

Lee et al. (2018) question the contentious increase in discharge in the Paraná River, which has been augmenting for the last 40 years without any corresponding increase in rainfall. They demonstrate that changes in river

METEREOLOGICAL DROUGHT IN THE BASIN



discharge correspond to periods of peak deforestation and changes in land use in the region and argue that such an increase is critical for its sustainable energy supply.

From a landscape planning point of view, the fact that changes in land use increase river discharge - in other words, that all rainfall is flushed in a much shorter time span - means more than a lack of sustainable energy supply. It means a disruption in the whole water cycle, which ultimately affects all human and non-human ecosystems within the basin, as seen during the drought event of 2019-2021.

The experience at the Loess Plateau in north-central China demonstrates this phenomenon. For millennia, unsustainable agricultural practices and land use caused a green watershed to deteriorate, causing freshwater stress and food insecurity. According to the World Bank, deforestation and changes in land use escalated over time to a situation where 95% of the rainfall would be lost to surface runoff, as opposed to slowly infiltrating the root system and the aquifer and then being released into the Yellow River. This thesis learns from the Loess Plateau as a case study because a similar process occurs in the Paraná River Basin.

To conclude, even though there is no consensus on the extent of land use's role in drought events, such as the one experienced between 2019 and 2021, it is a consensus that it does play a role. As a design discipline, Landscape Architecture can prepare the territory to withstand such events better and not contribute to them. It is simultaneously a matter of adaptation and mitigation so that future hydrological anomalies do not get as severe and geographically spread as during this recent and traumatic experience.

HYDROLOGIC DROUGHT IN THE BASIN

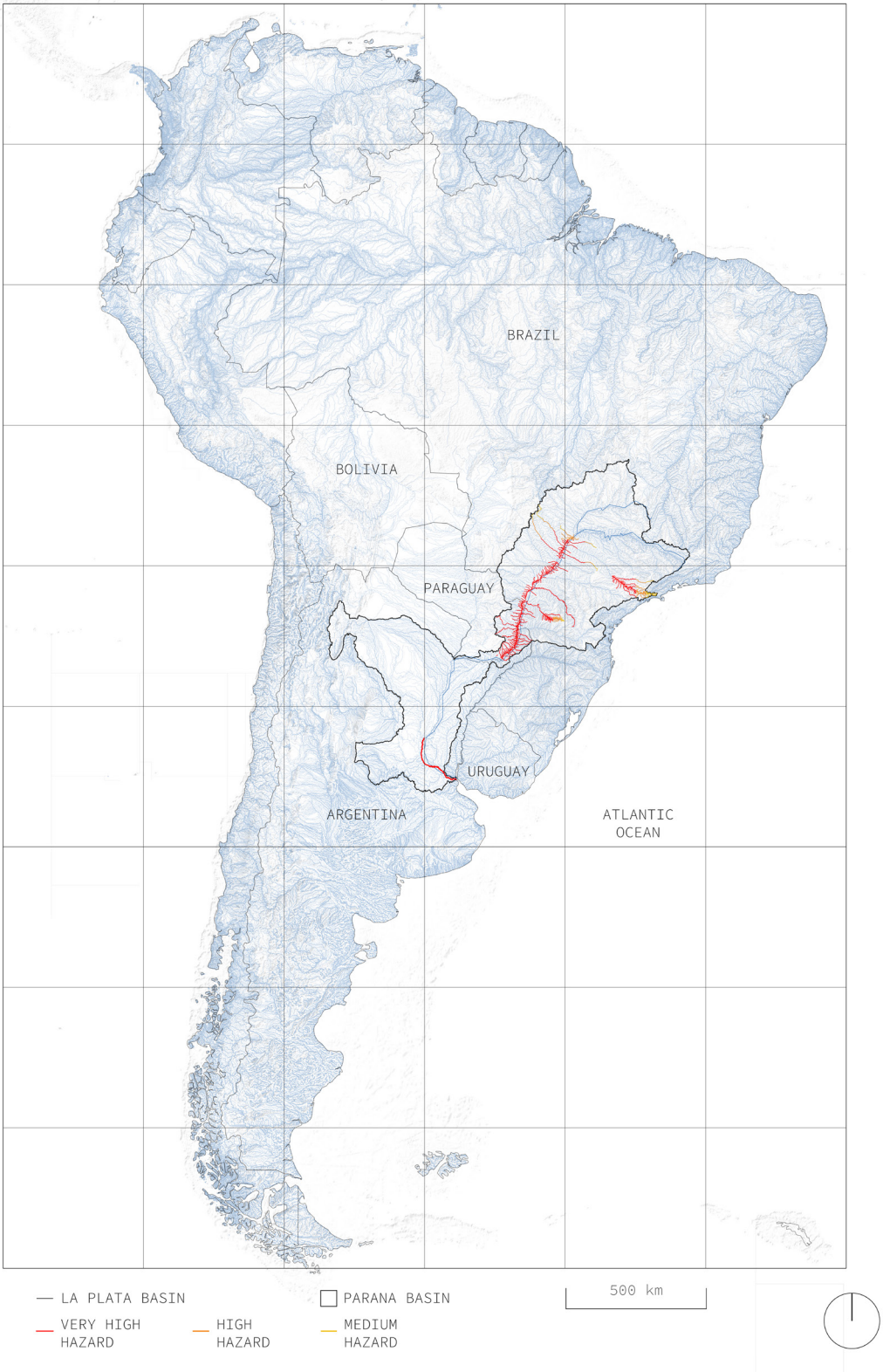


Fig. 03. Exposed shores in the Paraná River.

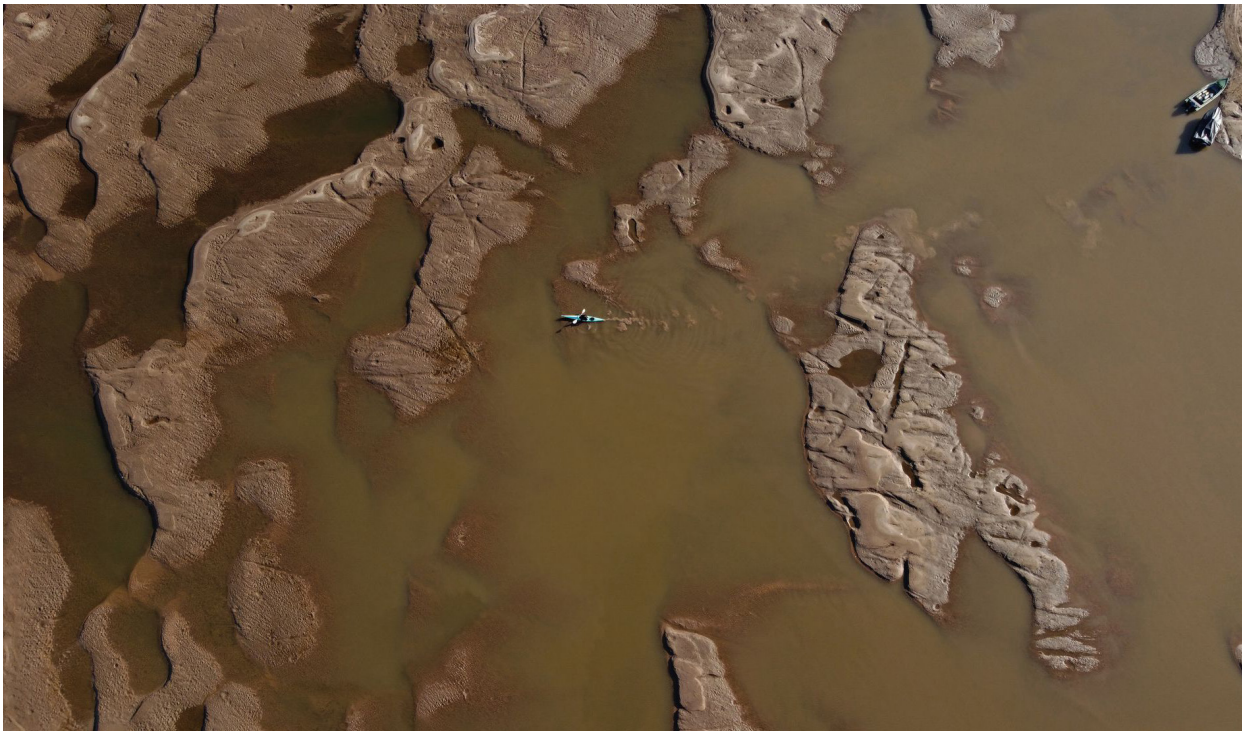


Fig. 04

Fig. 05

01.04 Research structure

01.04.01 Problem statement

As a culmination of the information stated above, this research posits the following problem statement:

As early as 1833, when Charles Darwin was researching South America, local inhabitants would already report the Paraná River as subject to intense seasonal floods and droughts. Almost 200 years later, anthropogenic climate change has arguably worsened the cycle, as wet seasons become less wet, and dry seasons become even dryer. Climate predictions for South America point to even deeper variations. In 2019, the Paraná River basin presented the lowest water levels in 77 years, causing economic and environmental damage. The landscape was marked by marshlands drying, vegetation burning, shores exposed, and sandy islands appearing in the river, with fish stranding due to the shallow water. Current human occupation and management of this landscape only exacerbate drought, as the previous Atlantic Forest, a rich biodiversity hotspot, got replaced by a tapestry-like commodity landscape woven by the hands of agribusiness titans and moulded by the Plantation model (Haraway, 2015). Sugarcane plantations, grazing fields for livestock, and eucalyptus forests are extensive to the point that they reach the horizon. While lucrative, these forms of land use are problematic because they facilitate soil erosion, compression and impoverishment, sharply decreasing water retention capacity. Therefore, the Paraná River basin has a reality of severe threats and structural vulnerabilities. To avoid further socio-environmental and economic losses, spatial occupation in this basin has to be rethought, taking the physical landscape and its remaining ecological processes as the basis. As the basin is home to millions of people and an established commodity-oriented economy, frameworks and spaces that allow for new forms of coexistence should be considered as a strategy for mitigating drought.

01.04.02 Research objective

In order to address such pressing issues, research questions were formulated as a framework to guide the research:

Main research question: How can adaptive spatial design, developed upon a landscape architecture approach, enhance water retention and resilience in the Upper Paraná River basin in light of drought and uncertain future challenges?

Followed by three sub-questions:
A: [About the system, the challenges and potentials] How did the Paraná River Basin socio-ecological system work before, and how does it work currently? How did deforestation and agribusiness impact it? What are the main challenges and potentials of the current physical and cultural conditions?

B: [About principles for the basin] It is impossible to rebuild past "pristine" baselines because the basin is now home to millions of people and a robust agribusiness-based economy. Given these current conditions, what are the fundamental landscape architecture-based principles and strategies capable of negotiating with such, enhancing water retention capacity and resilience within the Upper Paraná River Basin?

C: [About design application] How can these principles and strategies be translated into situated landscape architecture design?

In summary, this research aims to understand how landscape architecture as a design discipline can enhance resilience against climate-related disturbances in vulnerable territories in the context of South America and other Plantation landscapes around the world. The expected outcomes can be organised by subquestion, as follows:

Sub question A) Text and graphic material about the previous and current Paraná River system.

Sub question B) Set of landscape-based principles, based on the analysis carried in A)

Sub-question C) Three situated landscape architecture interventions, testing the application of the principles developed in B, and depicting how a regional strategy can exist at a small scale.

01.05 Methodology

The methodology for this research can be summarised in two different moments, consisting of collecting and processing information and its application. The information collection happened through a short literature review on the different themes believed to be relevant and through a study trip to the city of São Paulo and the Upper Paraná River basin, which took place in January 2023. The stay in São Paulo consisted of two visits to the State Archive to consult historical documents on the exploration and exploitation of the Upper Paraná River basin and a visit to a conservation unit working with ecosystem regeneration. When visiting the Upper Paraná River basin, based at the city of Três Lagoas - which is the biggest city along the Paraná River and the easiest to access -the author visited a cellulose production plant, its associated eucalyptus plantations, local leisure spaces, sugar cane plantations, and conservation units, where she could talk to local agents, collect materials (soil, plants, cultural artefacts) and take pictures.

The processing of information consisted of all the data collected from the Internet and translated into a series of maps, giving a geographical perspective to the issues the thesis is dealing with. Finally, the application phase consisted of the formulation of principles based on the information collected, which then were applied to a case study, which was the city of Três Lagoas; because of its representative assemblage of land use, significative population and the fact that it was the place the author could visit. The result of this application was a masterplan, or regional design, which is further explored by three zoom-ins that aim at illustrating how the issue of hydrologic dysregulation can be addressed at the human scale, with its intrinsic negotiation between ecology, economy and culture.

Each of the three Zoom-ins has a specific methodology. Zoom-in A has a stronger emphasis on cultural aspects, so it has been developed through more conventional spatial design methods, such as drafting and model making, which allowed the researcher to explore the spatial experience of the project. Zoom-in B revolves around ecology, so it has been informed mainly by a literature review and oral information from local practitioners. Zoom-in C explores the developments of land-forming interventions along the Paraná River regarding water retention, ecological value and leisure, so it departed from experiments made at the Department of Water Management, with the assistance of Dr Ir. Olivier Hoes.

01.06 Relevance

There is a local and global relevance to researching the 2019 drought event in the Paraná River. At a local scale, it means the search for strategies to recover from the disturbance while building a more robust territory to withstand future changes. South America is expected to experience further shifts in rainfall patterns, leading to new drought and flood events (IPCC, 2022), proven to cause massive biodiversity loss and socio-economic distress. Furthermore, as it will be discussed further, the Upper Paraná River basin is an industrial, agricultural landscape, producing and exporting commodities to the world, which means it is highly vulnerable to climatic disturbances. The fact that it is an essential region in a global supply chain also means it can cause wide-scale shortages when severely impacted.

Continuing at a global scale, investigating the 2019 drought event can give insights into a problem that will only become more frequent. That is because industrial agriculture landscapes are everywhere: the Paraná River basin is no longer unique. It is a product of a generalising model of global scope, which will be further explored in the following chapters. The lessons learned from this research will hopefully be meaningful discussion topics for climate adaptation in other parts of the world.

01.07 Itinerary

This report is organised into three chapters hereafter. Chapter two, “Analysis: A Landscape of Structural Vulnerabilities”, provides a more profound overview of the Upper Paraná River basin from a spatial perspective, with inputs from a literature review and a study trip. Chapter three, “Regenerating the Hydrologic Cycle”, sets the theoretical basis for a landscape architecture intervention, arguing for three principles that could guide tackling the issue. Chapter four, “How can principles become spatial?” works towards a physical translation of the position developed in the previous chapter. Finally, chapter five, “Developing a Position in Landscape Architecture”, elaborates on the main research question and the limits and possibilities of the discipline.

02. Analysis:
A Landscape of Structural Vulnerabilities

02.01 Introduction

This chapter starts by investigating how the existing land uses in the Upper Paraná River basin interfere with water retention capacity; in other words, how the modes of placemaking characteristic to the industries of sugar cane, wood pulp and cattle ranching impact the hydrologic cycle. This analysis is followed by a comparison to the original dynamics of the landscape, comprehending its native biomes and inhabitants, built upon a brief literature review of texts by ecologists and sociologists. However, if the current land use is unsustainable, why is it in place? An analysis of the Plantation model (Haraway et al., 2015) gives clues to understanding the mentality that guided the composition of this landscape's agricultural, infrastructural, and social layers. Finally, a reflection on the study trip that happened between December and January 2023 allows for a more immersive experience of the place.

Tributary of the Paraná River seen from the airplane during study trip.

02.02 Why is the current land use so vulnerable, and how does it amplify drought?

If, on the one hand, there were significant precipitation anomalies from 2019 onwards, on the other, it is hard to imagine more vulnerable sorts of land use than the ones to be found within the Upper Paraná River basin. Even if climatologists have not yet found a consensus on which factor to blame first, a closer look at the little water retention capacity proper to the typologies of monoculture fields, cattle ranches and overly sprawled cities makes it clear that occupation played a significant role in the drought event of 2019-2021. While the region seems to slowly go back to standard precipitation patterns in 2022 and 2023, it continues to have a spatial occupation of little resilience, which is attested by less broadcasted issues, such as the continuous drop of the Guarani's aquifer levels, of up to 2 metres per year[01].

What are the spatial characteristics of the main land uses in the basin from a water retention point of view? Firstly, monoculture crops are widespread and consist primarily of sugar cane, soybeans, coffee and orange. There is a poignant issue with soil life, in sharp decline because of the lack of diversity in the root system, the litres of fertilisers fed without consideration for widespread consequences for the living organisms within it (Instituto Florestal, 2010), constant ploughing and subjugation to the pace of production of highly demanding crops. These factors lead to dead soil with less capacity to retain water, which is less appropriate for deep infiltration and aquifer recharge. Dead soil in complete exposure to rain after every harvest season can only generate enormous amounts of topsoil erosion, with values between 15 and 25 tons/ha/year. This disrupts the water cycle because it causes the silting up of rivers, water springs, and water eutrophication. The fact that only a 30-metre offset of riparian vegetation is protected by law from monocultural fields (Diário Oficial da União, 2012) is not enough of a filtering buffer to prevent these issues from happening. Finally, the existence of one single vegetal stratum facilitates the loss of water to evapotranspiration.

Extensive livestock ranching has the same issues as monoculture plantations, plus the fact that cattle are constantly stepping on the soil, making

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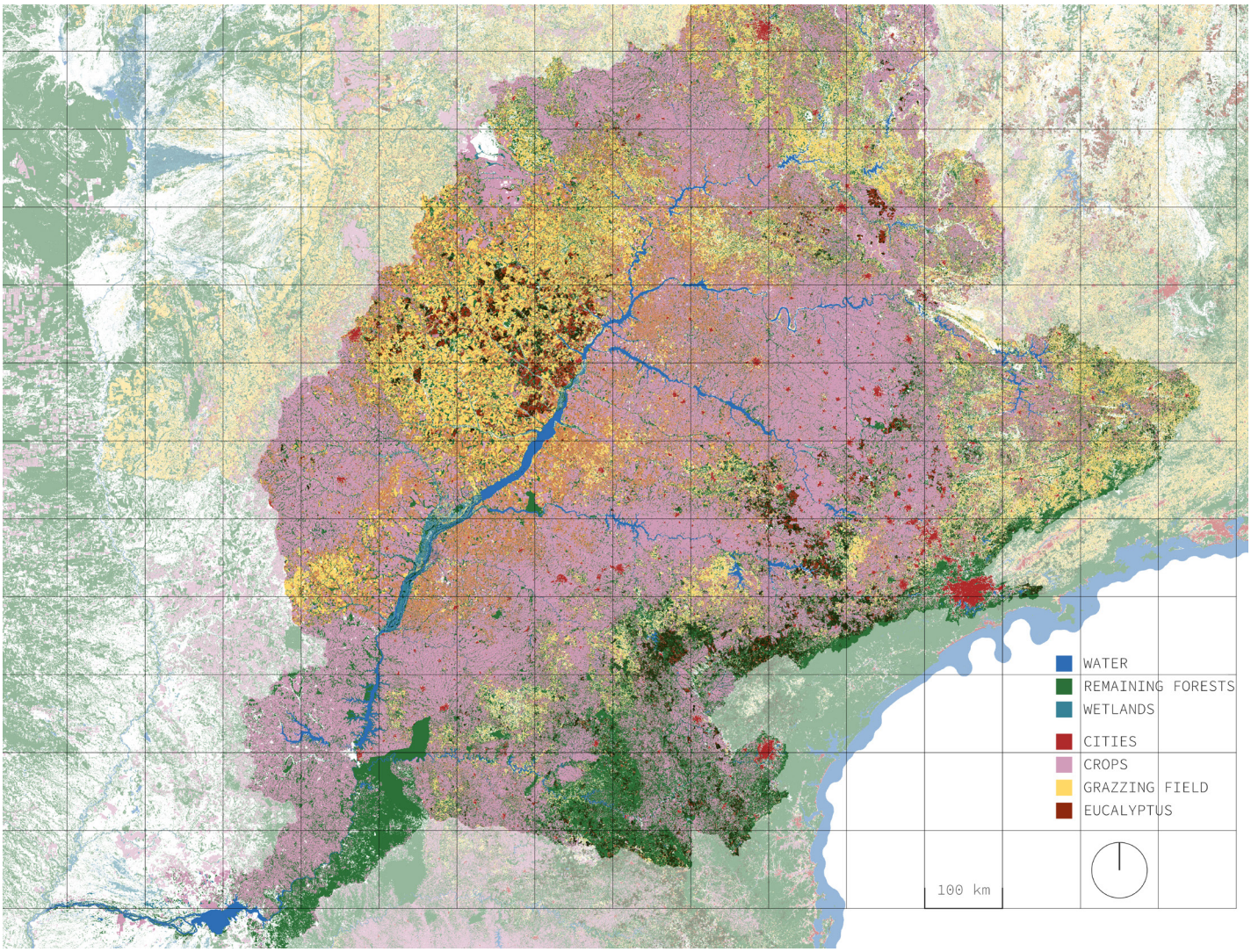
01 https://g1.globo.com/sp/ribeirao-preto-franca/noticia/2021/09/19/nivel-do-aquifero-guarani-em-ribeirao-preto-sp-cai-120-metros-nos-ultimos-71-anos-diz-estudo.ghtml

LAND USE IN THE UPPER BASIN



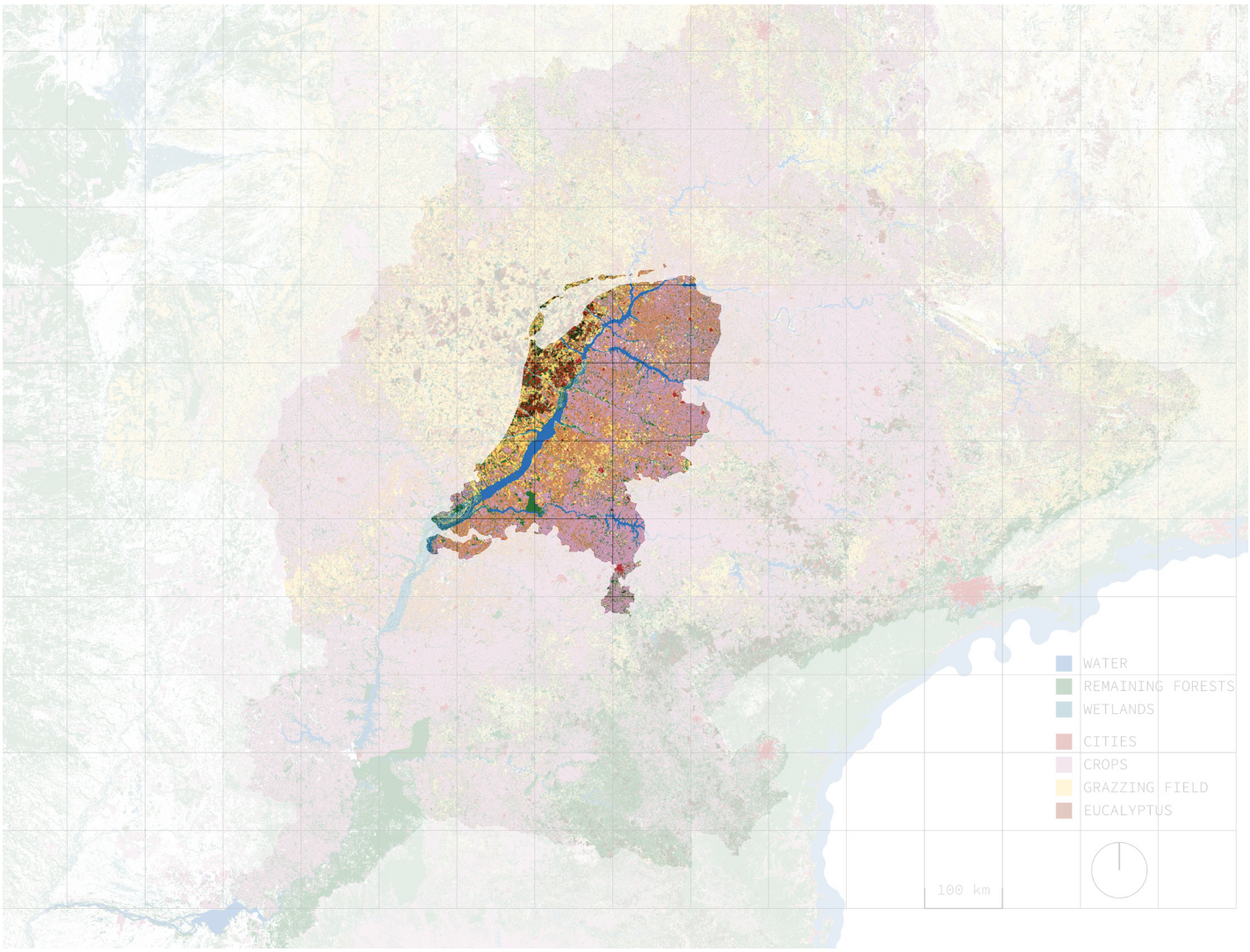
All types of land use of the Upper Paraná River Basin combined.

it more compact and impervious to water. A grazing field is a plantation as well. It is a monoculture of exotic forages, eroding soil life due to a lack of biodiversity and high nutrient demands. There is a pressing issue with using a type of grass called Brachiaria brizantha, originally from Sub-Saharan Africa and widely adopted by ranchers in South America for its high adaptability and ability to suppress competitors such as weeds or native seedlings. The use of exotic species should not be considered a problem per se, but from that point, they start out-competing native species and generating a decline in local biodiversity.

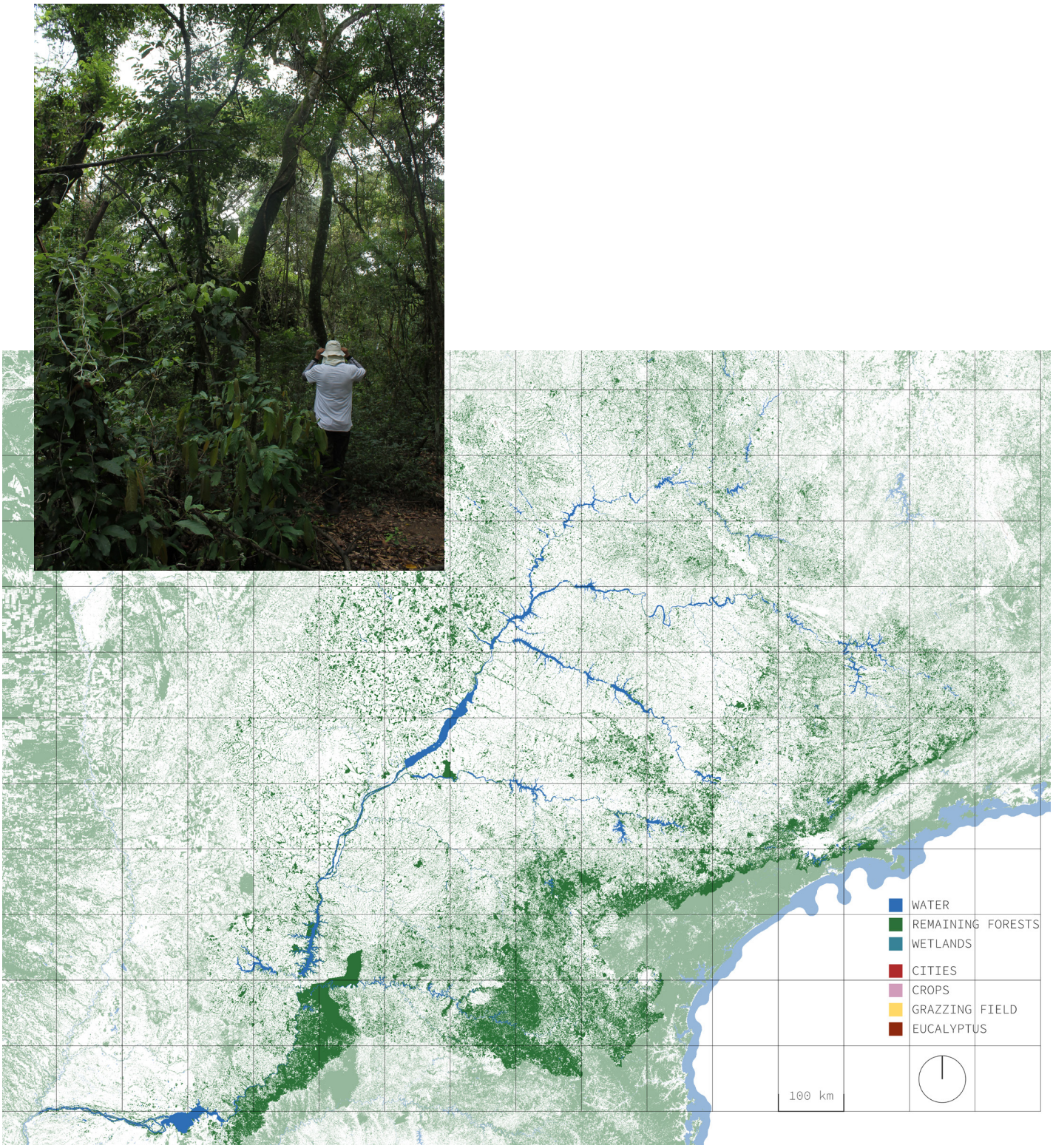
Both monoculture and grazing fields deserve a comment on biodiversity loss. Besides the monotony of their compositions, they also entail a lot of ecosystem fragmentation, where forest continuums are reduced to sparse patches of greenery in constant decline due to edge effects. The connection between biodiversity loss and reduced water retention is related to declining soil life and the erasure of different vegetal strata capable of retaining moisture and less resiliency against disturbances. The connection with resiliency stands for the principle that different beings can withstand different disturbance scenarios, which implies that a more diverse ecosystem is less prone to complete decline during a drought event, for example.

Lastly, urban areas around the Paraná River have mainly started as settlements of workers in the coffee industry (previous economic cycle) throughout the 20th century. Because space availability was not an issue, cities tended to sprawl freely, generating urban typologies of large grid-like settlements occupied by one or two-storey buildings. This typology creates long distances on impervious concrete surfaces, usually travelled by car. Therefore, urban areas also have a pressing problem with floods and their counterpart, lack of water infiltration.

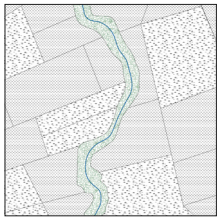
COMPARING SCALES



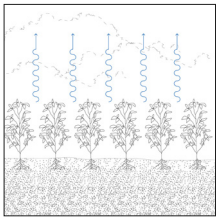
Graphic comparison between the Upper Paraná River Basin and The Netherlands (same scale).



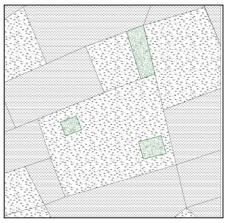
Remaining stretches of Atlantic Forest.



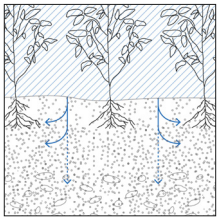
Loss of riparian buffers



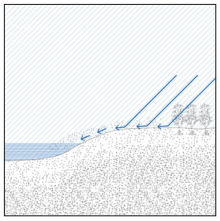
Excessive evapotranspiration



Habitat fragmentation

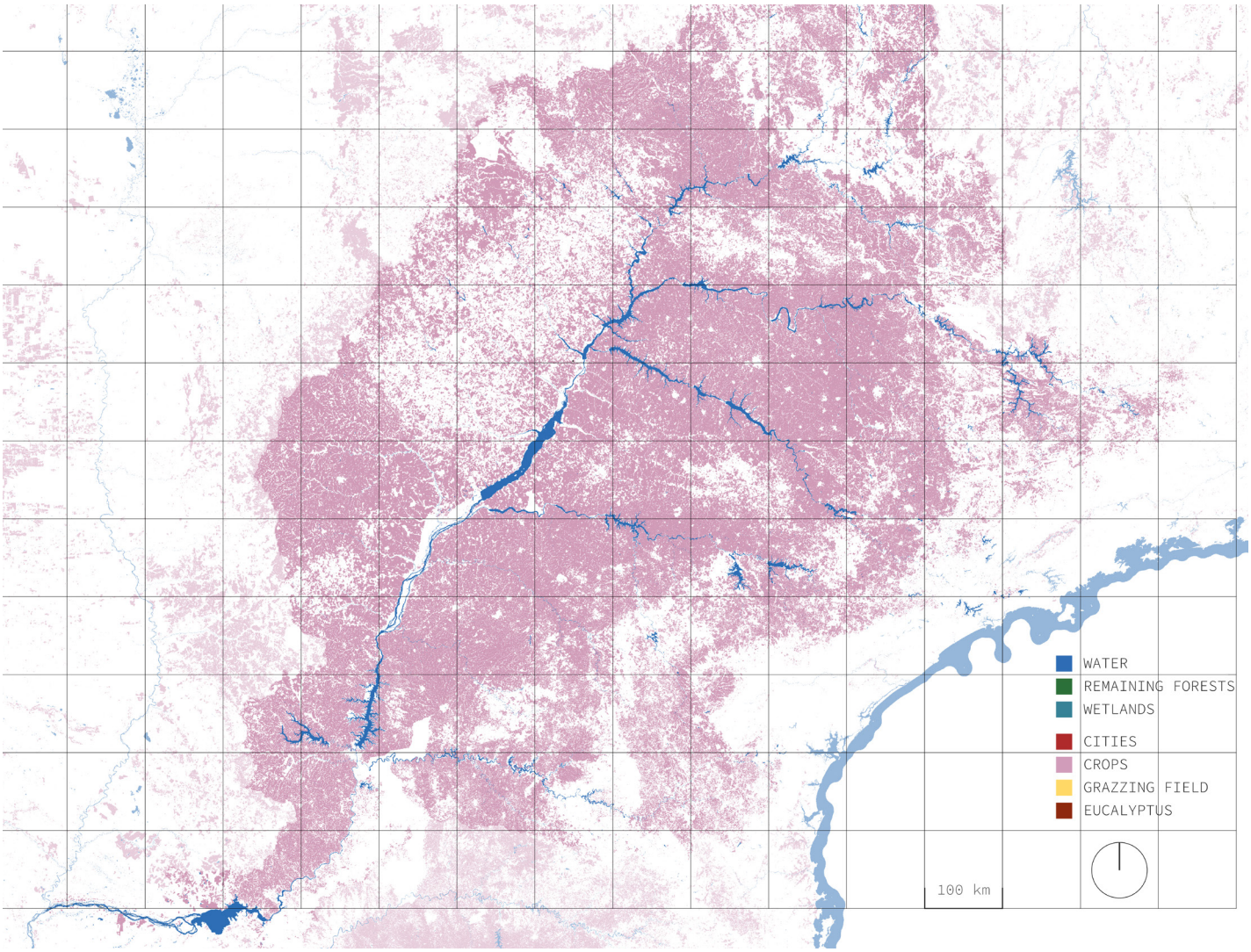


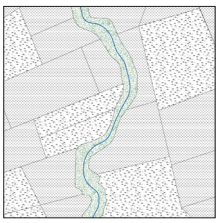
Loss of soil life, less deep infiltration



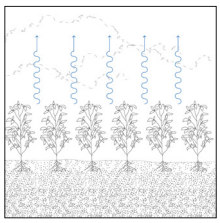
Excessive erosion, silting up rivers

THE EXTENT OF CROP PRODUCTION

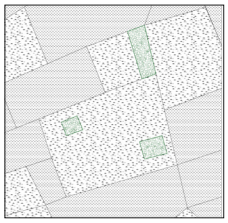




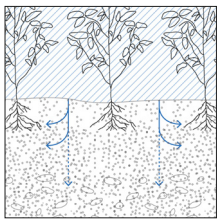
Loss of riparian buffers



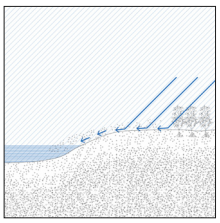
Excessive evapotranspiration



Habitat fragmentation

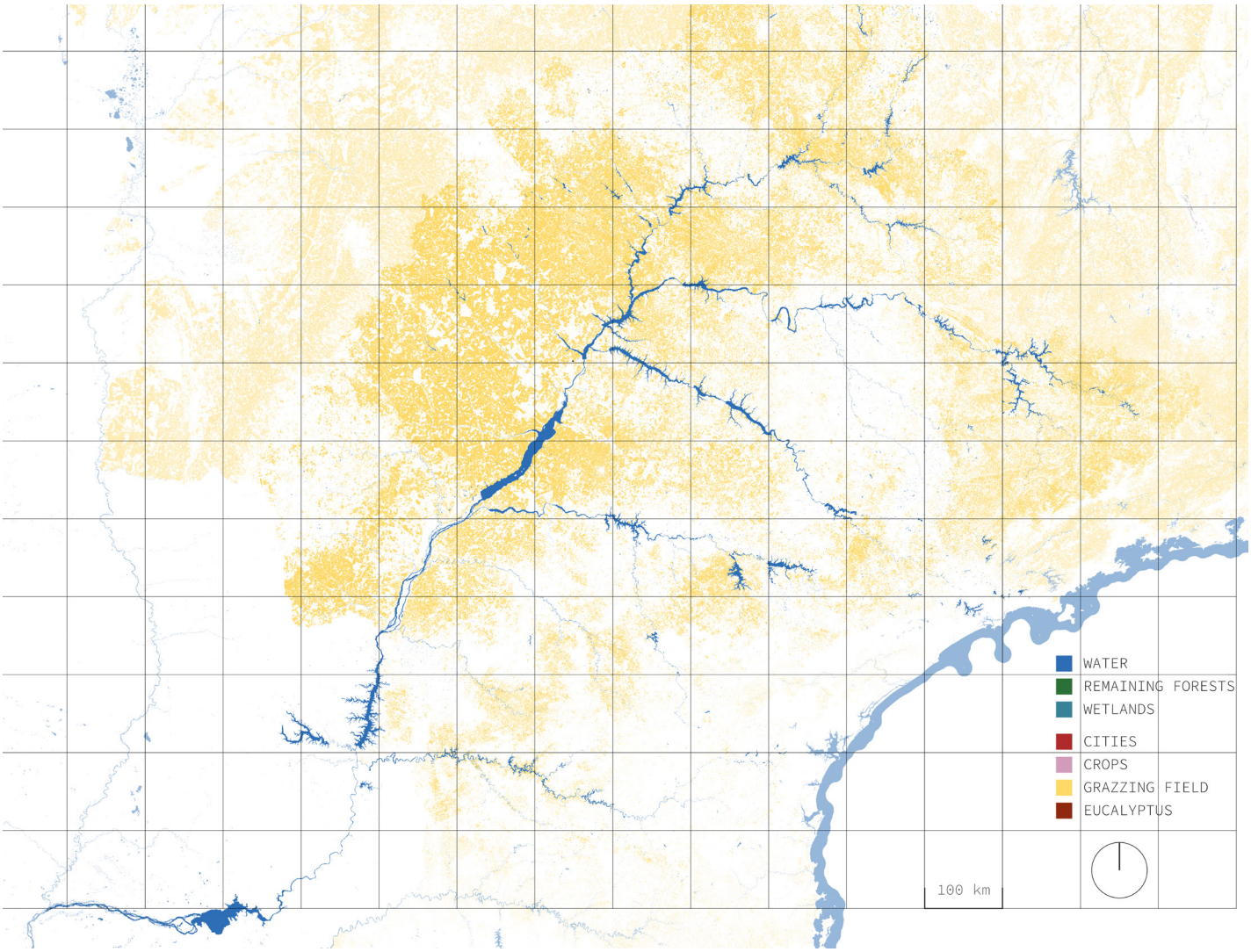


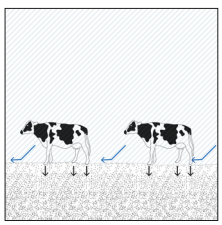
Loss of soil life, less deep infiltration



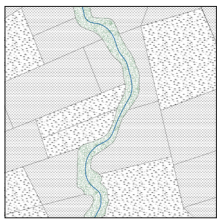
Excessive erosion, silting up rivers

THE EXTENT OF MEAT PRODUCTION



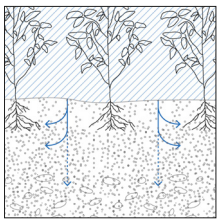


Constant compactation

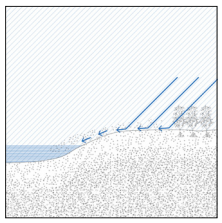


Loss of riparian buffers

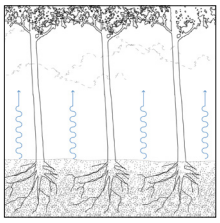
Habitat fragmentation



Loss of soil life, less deep infiltration

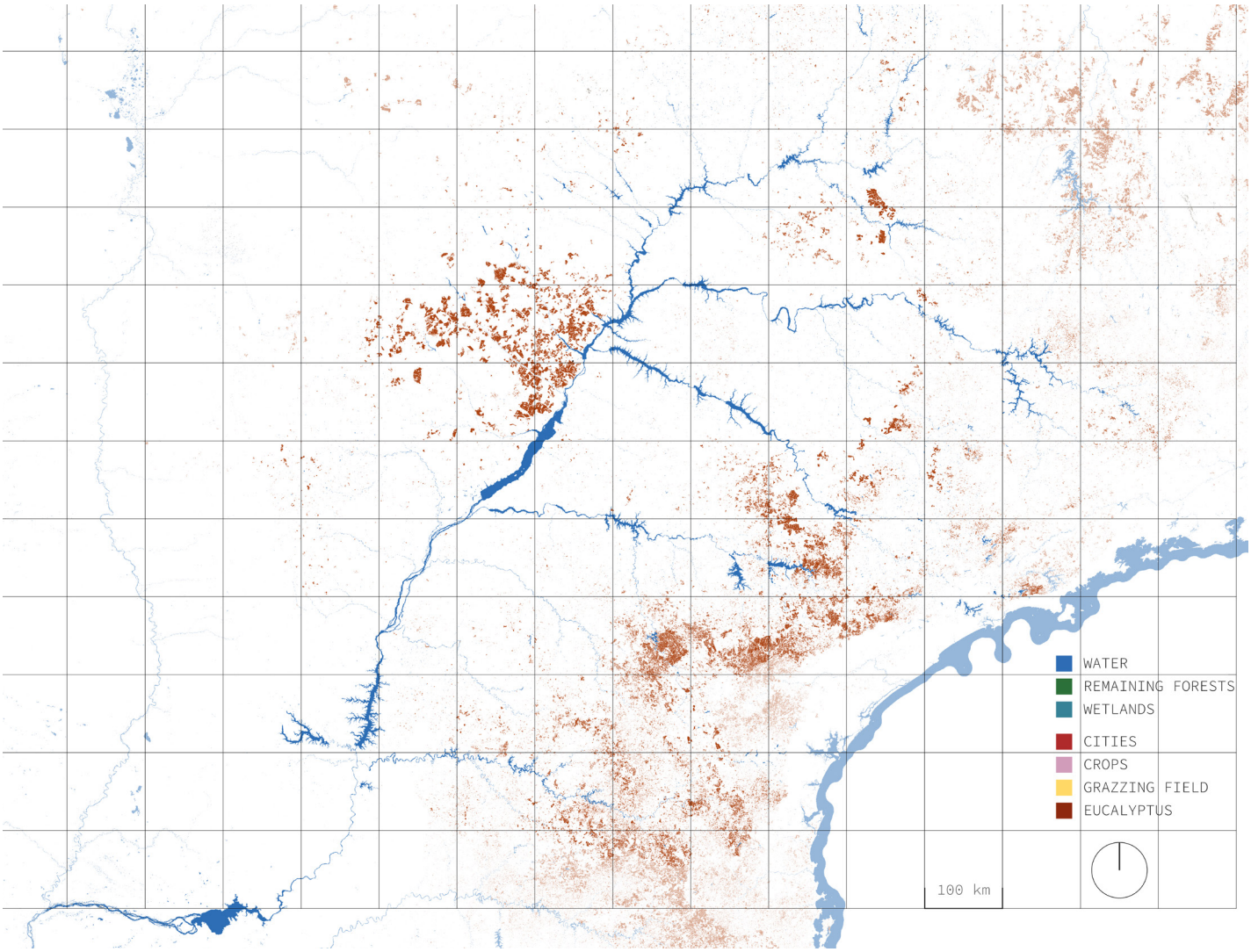


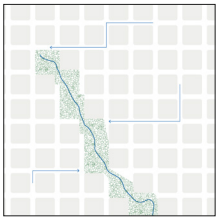
Excessive erosion, silting up rivers



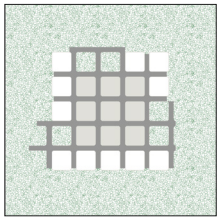
Lack of diversity, lack of varied strata

THE EXTENT OF WOODPULP PRODUCTION



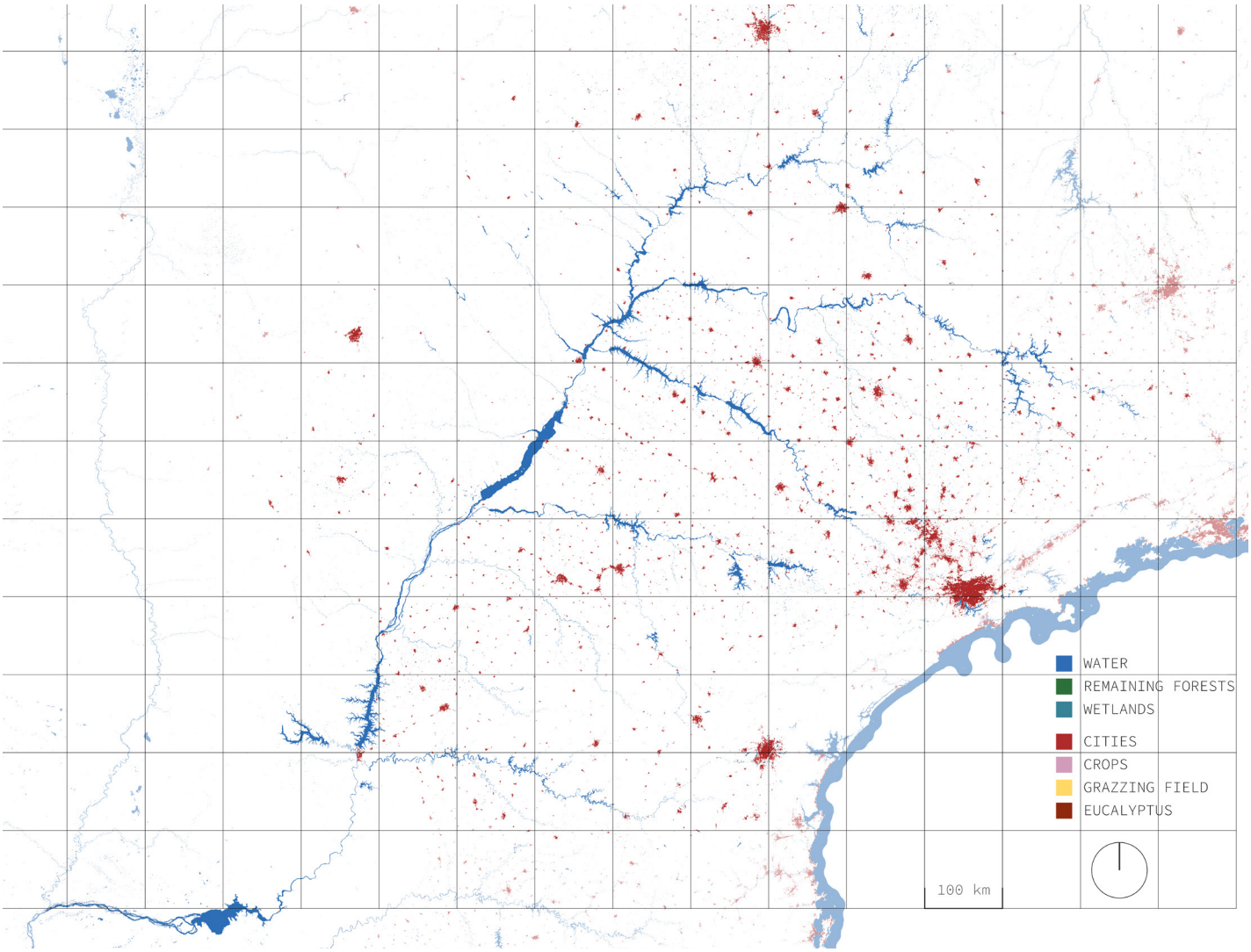


Loss of riparian buffers



Excessive sprawl, little verticalization

THE EXTENT OF URBAN SPRAWL



02.03. The landscape from before

02.03.01 Riverine ecosystems

The Paraná River used to be a robust biological corridor linking Brazil's central area to Argentina's northern area. Every year, birds and animals would migrate along its waters in both directions. Food and refuge were easy to find in the heterogeneous landscape of marshlands, shallow lakes, parallel channels, and riparian forests.

The ecosystems immediately around the axis of the Paraná River were of remarkable dynamism. The seasonal fluctuations in water level would cause the connectivity between entities to vary. For example, during the wet season, many isolated lakes would be integrated into the main body of water, allowing nutrients and genetic material to circulate. On the other hand, during the dry season, isolated lakes and marshlands would emerge and develop specific entanglements of plants and animals. Some fish and plants seek still water (lentic), while others seek flowing water (lotic), and both would have the opportunity to find their preferred habitat along the river. In a nutshell, seasonal floods provoked dynamism in the level of connectivity between entities in the floodplain, which generated heterogeneity and, consequently, biodiversity (Collins & Marchese, 2020).

Seasonal fluctuations in water level carried out other processes beyond changes in connectivity. The longitudinal dynamics along the Paraná River brought sediment flows, creating sandbanks and bar-shaped islands. Sometimes such sedimentation processes would cause a parallel floodplain channel to get isolated from the main channel, thus becoming an isolated lake with its own biological grouping. It is estimated that 90% of the lakes that existed in the basin originated from these processes (Iriondo et al., 2007). They provide important habitats for plants and animals, usually composed of two types of habitat: enclosed banks occupied by aquatic plants (macrophytes) and a central part consisting of free open water. The vegetated banks are complex enough to sustain a high level of diversity (Fantin-Cruz et al., 2008, cited in Collins and Marchese, 2020). Shallow lakes also perform important water retention roles, as the water residence time in a connected lake is between 7 to 10 days and up to 365 days in an isolated one (Iriondo et al., 2007).

The Upper Paraná River Basin landscape changed enormously after the implementation of approximately 140 dams, all in Brazilian territory and aimed mostly at electricity production. What used to be a dynamic river now resembles a series of lakes, even though Collin and Marchese (2020)

state that their water flow is somewhere between that of a lake and a stream. The damming of the Paraná River caused a deep loss of habitat, a number of threats to water quality in the system, and a disruption in the former hydrological cycle.

When a dam is built, it causes big areas of floodplains to disappear under the newly imposed water level. Indeed, the borders between the reservoirs and the surrounding vegetation are currently sharp, because the water surface is now reaching what used to be higher terrains occupied by stretches of Atlantic Forest. On the other hand, the construction of a dam likely causes the downstream area to become dryer than before. This, combined with the fact that seasonal fluctuations are now partly human-controlled, causes many of the mentioned parallel channels, shallow lakes and marshlands to dry (Junk et al., 2014). It is reasonable to believe that seasonality is currently better manifested in a transverse section cut - that is, storm runoff coming from higher lands towards immediately correspondent floodplains -, which might be the driving force behind remaining forms of dynamism, such as marshlands or lakes appearing and being sustained.

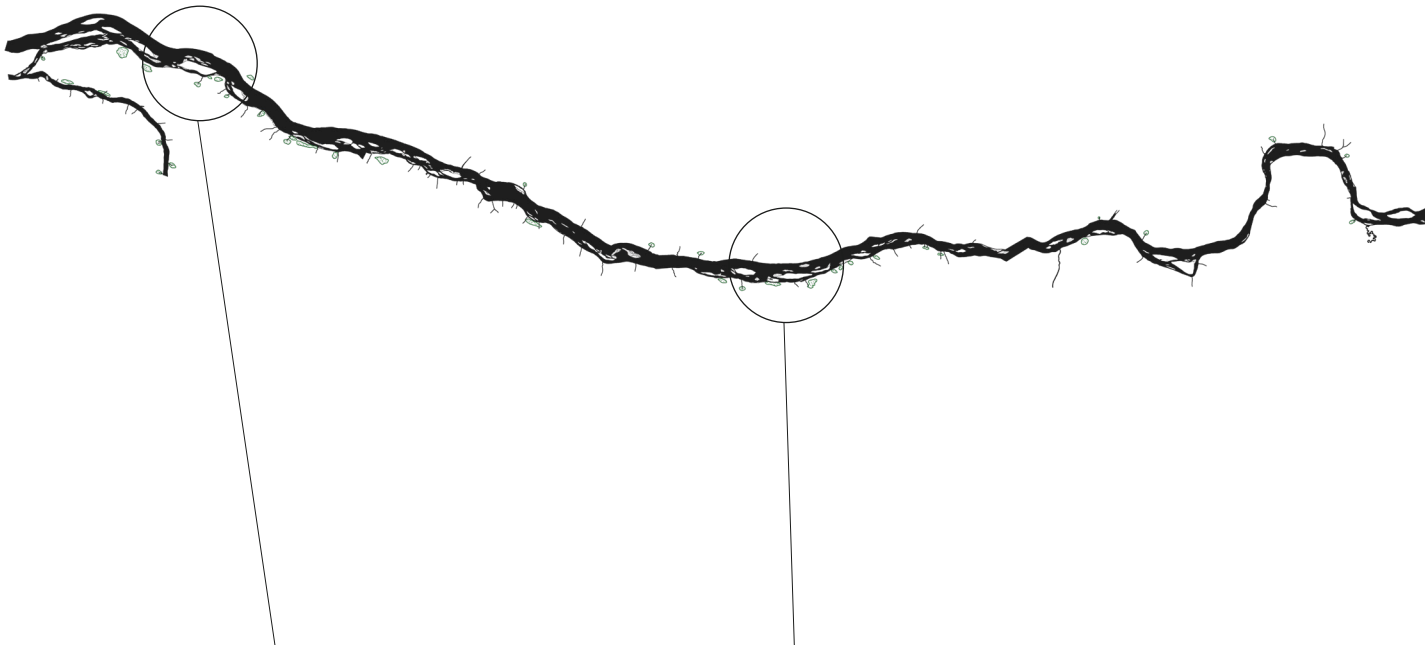
Furthermore, the combination of deforestation, use of agrochemicals, and damming of rivers is strongly harmful to water quality. Tundisi and Matsumura-Tundisi (2020) studied the ecology of reservoirs in the Upper Paraná River Basin and warned of how the processes mentioned above, coupled with urbanisation and industrial development, contribute to high levels of water eutrophication and sedimentation in the basin. Eutrophication is the process where an explosion in the algae population is caused by excessive accumulation of nutrients and sediments in a body of water, which degrades oxygen availability for other living species in the same ecosystem.

At an ecological level, the change from flowing to stillness distresses many fish who are used to either one or the other. Metcalfe and Menome (2020) explain that, because many fish depended on flowing water to reproduce and have the earlier stages of their lives, the protected riparian banks of tributary rivers and streams are their last haven in this altered landscape.

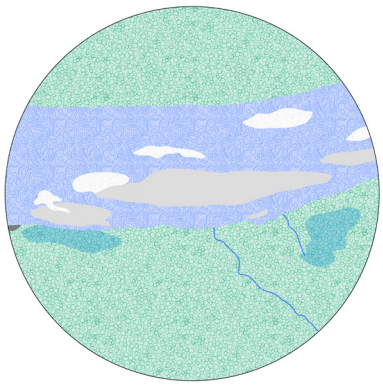
As put by Collins and Marchese, “the loss of heterogeneity of the system is the main threat to biodiversity and the maintenance of healthy ecosystems within the basin”, and the re-creation of dynamism within the now-artificial landscape, in consonance with the current socio economic framework to a greater or lesser extent, remains as one of the biggest design challenges.

Fig 06. Stretch of the Paraná River that has not been flooded by dams.

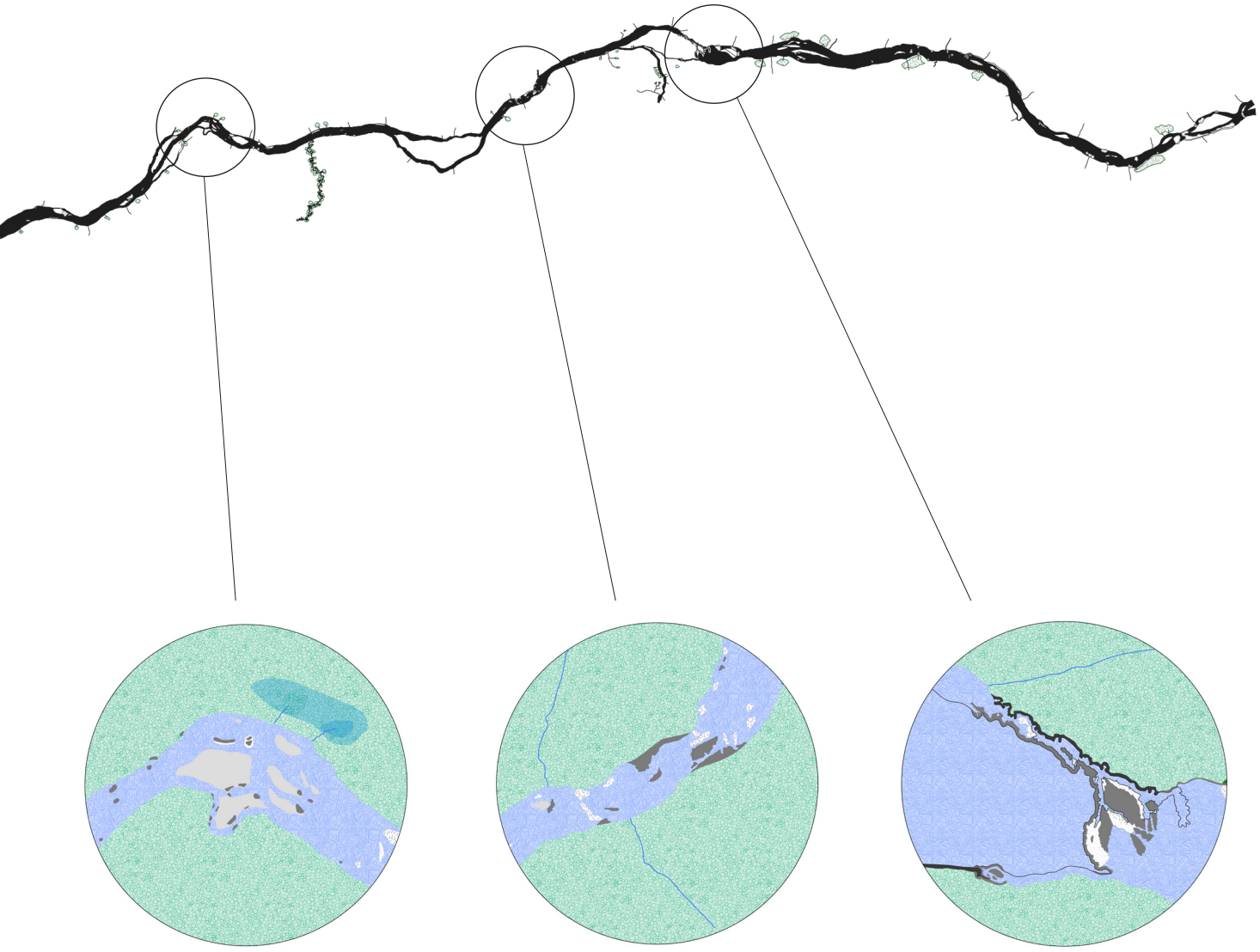
ORIGINAL FEATURES TO BE FOUND ALONG THE RIVER



riverine islands



sandbanks


marshlands
waterfalls
rock formations

COMPARISON: PARANÁ RIVER FROM BEFORE, PARANÁ RIVER AS
A SERIES OF HYDROELECTRICAL RESERVOIRS

02.03.02 Inland Ecosystems: Atlantic Forest and Cerrado

The Paraná River basin is located at a transition zone between the biomes of the Cerrado (Tropical Savannah), to the right of the river, and the Atlantic Forest, to the left of the river.

The Atlantic Forest is a biome under tremendous pressure of extinction. Its destruction began on the same day as the colonisation of Brazil by the Portuguese crown (Morelatto & Haddad, 2000), powered by economic interests represented by timber, firewood, charcoal, agriculture, cattle ranching, and the construction of cities. Only 7,6% of its original coverage is believed to exist nowadays in a highly fragmented manner. Its deforestation is considered one of the most alarming conservation issues in the world (Mori et al., 1981; Terborgh, 1992; Viana et al., 1997) since current data suggests it once was more diverse in endemic species than Amazon forests.

Originally, the Atlantic biome occupied a significant portion of the Brazilian coast and a part of the hinterlands in the South Eastern portion of the country. The portion on the coast is called the Atlantic Rain Forest, and the portion in the hinterlands is the Atlantic Semi-deciduous forest, which reaches the Paraná River at its plateau. While the first has no dry season, the Atlantic Semi-deciduous forest experiences a very wet and relatively severe dry season, usually occurring from April to September (Morelatto et al., 2000). The regional climate is Subtropical Humid, and the dry season happens during the winter (Cwa, according to the Koeppen system). During the dry season, the monthly average rainfall is less than 100mm, while the average rainfall is usually around 1247mm.

Conservation studies of the Atlantic Forest always address the pressing issue of habitat fragmentation. Tabanez and Viana (2000) studied the current patch composition and dynamics in different fragments of the Atlantic Forest surrounded by sugar cane plantations, which is valuable knowledge for regional landscape planning in this research. They identified that forest fragments are usually formed by four different units: the Low Forest (LF), a gap-like formation with no large trees, covered by liana tangles and between 0.5-4.0 metres tall; bamboo forest (BF), formed by bamboo tickets and not so occupied by lianas; high forest (HF), with an open canopy of 10-15 metre tall with lianas on the canopies and in the understory; and mature forest (MF), with large trees forming a dense canopy of 20-25 metre tall, no lianas and open understory.

Guide Adriano leads a visit to a preserved patch of Atlantic Forest.

The authors could draw two primary dynamics within the patches from this study. The first one is that even small patches (0.7 to 10ha) have a high level of biodiversity but are declining faster because of a lack of genetic flows - which calls for urgent preservation attention on the smaller fragments. The second one is that lianas can profoundly undermine forest regeneration, which is a conclusion that might be valid for other tropical forests. They proliferate quickly in the Low Forest and in gaps (whenever a large tree dies). They can hold natural succession back or even reverse it (arrested and retrograde succession) because of competition for light and nutrients. The authors state that high densities of lianas are a sign of disturbed or high-light areas, which explains their abundant presence in fragments, and that they can cause the decline of a patch even more than the edge effect. That entails that they must be human-managed in areas of desired forest regeneration.

Other common proposals from a small literature review on articles addressing habitat fragmentation in the Atlantic Forest underline the need to preserve even small fragments; the importance of connecting them with corridors to stop their decline and facilitate the movement of flora and fauna; the value of controlling edge effect (Morelatto & Haddad, 2000).

Even though federal laws and maps trace sharp lines between the Atlantic Forest and the Cerrado biomes, the actual situation is closer to a gradient-like transition, being the flora of the Semi Deciduous forest marked by similarities with the savannah formation (Oliveira-Filho, 2000). The Paraná River is in the middle of this complex mosaic of intertwined biomes. The Cerrado is a collection of vegetal formations occupying central Brazil's highlands, spanning from dry woodlands to savannahs, grasslands, and riparian formations. Because of its physiognomic variety, nomenclature and classifications are very debated, but for the goal of this research, it suffices to give a general overview of what the biome is.

The Cerrado, as general nomenclature, is the second biggest biome in Brazil, after the Amazon. It has a similar drought regime as the Semi-deciduous Atlantic Forest, with 1500mm mainly precipitating between April and September. Its soils are poor, acidic and rich in aluminium (Klink & Machado, 2005), which has been no obstacle for agribusiness to expand. Nowadays, only 21.3% of the biome is considered "intact", spared from pasture and cash crop agriculture, primarily soybeans and sugarcane. It is Needless to mention, all the problems that come with it: habitat fragmentation, loss of biodiversity, topsoil erosion, and changes in fire regime due to the biome's inherent dryness.

Despite its dryness and apparent inhospitality, the Cerrado is one

of the world's biodiversity hotspots, with more than 7 000 known species of plants, with 44% of endemism. Besides deforestation for the markets mentioned above, biodiversity is also threatened by its consequences, such as topsoil loss (up to 25 tons/ha/year) and the introduction of exotic grass species that proliferate quicker than the native flora, changing soil and fire regimes.

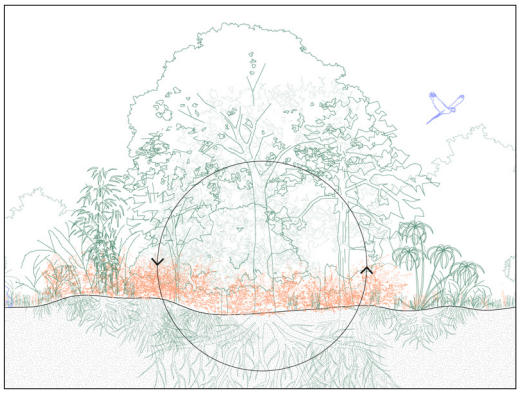
The biome's central physiognomic units are, from more enclosed to more open: the riparian forests, occurring along rivers and streams, reaching 20-30 metres in height and 70-95% of canopy cover; the "Cerradão", which consists of medium-tall vegetation of 30-40% canopy cover and 8-15 metres tall; then the broad "Cerrado, comprising sparse woodlands, grasslands and shrubby formations of 2-8 metres tall and rarefied vegetation cover (Ribeiro & Water, 2008). There are also "Palmeirais", a grouping of palm trees that were historically used as food for palm tree hearts.

Typical Cerrado formation close to the city of Três Lagoas.

02.03.03 Original inhabitants: the Chavante Indigenous people

As the team from the 1905 expedition reported, the Chavante indigenous peoples were present in the landscape. They are previously-nomadic groups of hunters and collectors that historically inhabited Central Brazil. They are now located mainly in an Indigenous Reserve at the transition between the Cerrado and Amazon Forest biomes, north of the Upper Paraná River. In the past years, more and more attention has been paid to their landscape management practices, which consist of a thriving human ecology system.

The geographers and explorers in the expedition reported seeing fire from afar. Indeed, one of the most well-known and documented Chavante practices is igniting vegetation for sustenance, territory management and cultural expression (Welch, 2021). They would set a low-temperature fire to the understory of Cerrado patches, burning mostly the understory, and then hunt the running animals escaping the fire. Even though much cultural shaming can happen because fire is now considered only as a cause of climate change, recent studies show that the Chavante practice barely deforests the landscape (Welch, 2013) and is regarded by ecologists as an inducer of resource availability, diversity and resilience. Actually, according to Kink and Moreira (2002), fire avoidance is also a problem, since nowadays' farmers wait to burn at the end of the dry season, when dry biomass is highly accumulated, resulting in scorching fires, to the point of being prejudicial to larger plants and soil fauna.

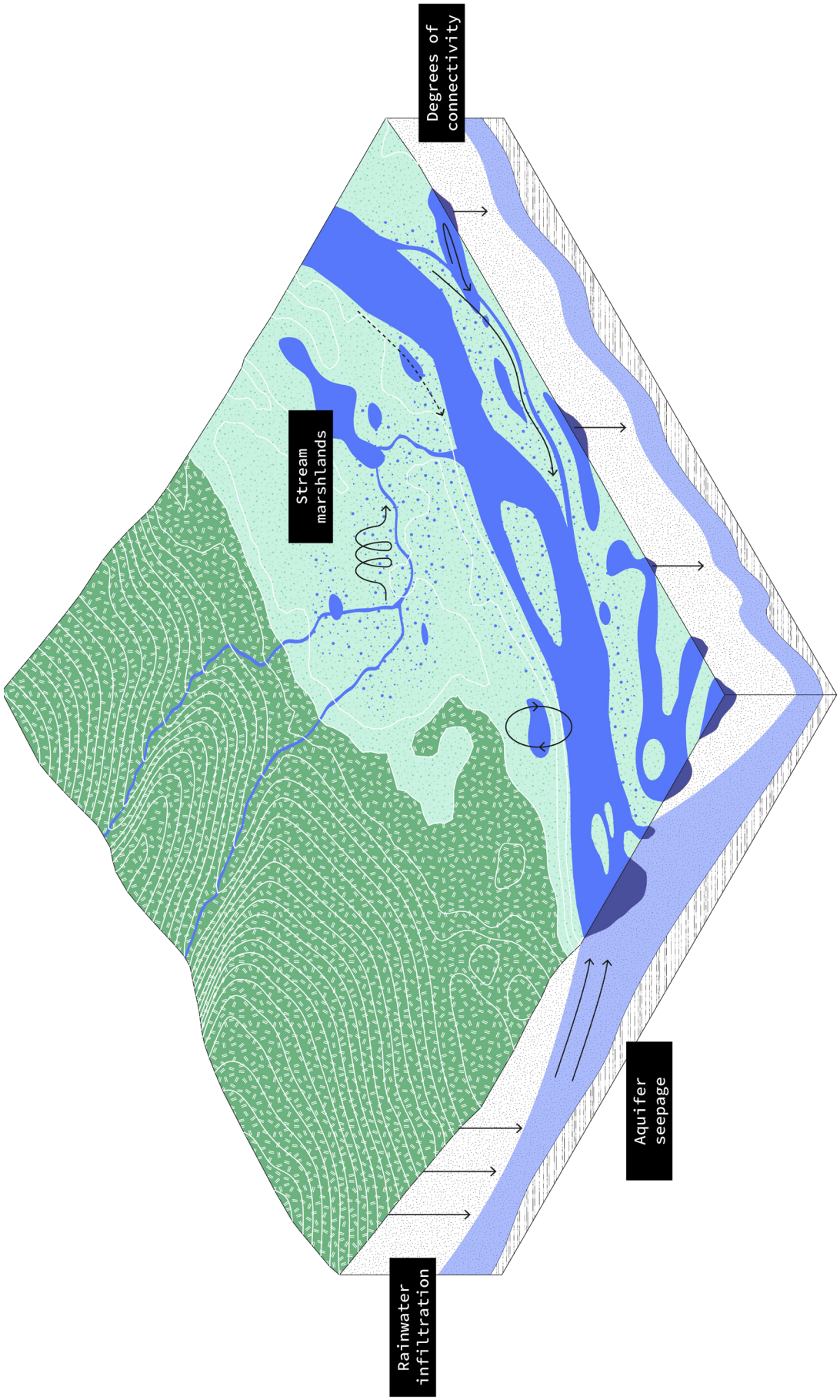


The positive outcomes of burning practices have two sides. The first relates to Indigenous landscape management knowledge, which assures that the same plot of land is not repetitively burnt within short periods, usually a decade or more. Also, fire prevents dry organic matter from accumulating too much in the understory so that regular small fires can prevent a potentially destructive serious one - it can be regarded as a 'maintenance' act. For the same reason, burning alternate patches of the landscape creates a barrier against severe fires because it interrupts the continuity of the dry understory biomass layer. The second relates to the Cerrado vegetation, which is highly adapted to seasonal fires because of the arid season. Tree trunks are thick, and plants generally have a big part of their biomass underground, as well as organs such as taproots, rhizomes and bulbs.

Meeting between members of the first expedition (1905) and Chavante people.

02.03.04 The previous hydrologic system

The research and literature review gives a general idea of the original hydrologic system in the area. It was a system of high water retention properties, in which rainwater would be held in the vegetated slopes and infiltrate the Guarani Aquifer for a long time. What would still flow towards the Paraná River would be retained for significant periods (up to 365 days) in the flatlands, forming the marshlands and side lakes. The Paraná River itself would be, to a great extent, fed by aquifer seepage from the Guarani. Therefore, in the Upper Paraná River Basin, rainwater would fall and take a long time to re-emerge in the river and get flushed downstream towards the lower basin, which resulted in a smaller but more consistent discharge over the year.


Degrees of connectivity
Stream marshlands
Aquifer seepage
Rainwater infiltration

02.04 The model of the Plantation

During one of our group conversations in the Resilient Coastal Landscapes Lab, another student asked me, "If this landscape is dysfunctional, then why is it like this?". As straightforward a question as it is, the answer was not easy. It took time and research to understand that the Paraná River basin as it is nowadays is not a unique landscape but a product of a model that has been reproduced at a global scale. Such a model is not apolitical, and scholars have been linking it more and more to the ongoing ecological crisis the world is experiencing.

Like many other countries, Brazil is a former colony. The Portuguese crown ruled and exploited it for more than 300 years, from 1500 to 1822. Malcolm Ferdinand (Ferdinand, 2021), an environmental engineer and philosopher from the French department of Martinique, has been advocating for a deeper understanding of the connection between colonialism and the aspects of what is frequently called the Anthropocene (anthropocentric climate change, loss of ecosystems, mass extinctions, among others). He criticises the way colonialism is usually regarded as an exclusively social cause and the Anthropocene as a purely environmental one. He urges to demonstrate how both are actually connected by what he calls a "double fracture". This "double fracture" is the result of one single model: the colonial way of dwelling on Earth, which consisted of intense exploitation of resources - be them human or non-human, soils or aquifers, flora or fauna, gold or uranium -followed by the transportation of such to faraway lands (of people from West Africa to the Americas, of commodities from the Americas to the metropolises).

Therefore, the main epistemological shift Ferdinand posits is the understanding that colonialism should not be reduced to the relationship between groups of humans but also to the relationship between a group of humans and groups of other-than-humans, landscapes, ecosystems, and lands. If slavery is the social facet of it, the plantation (of cotton, coffee, sugar cane, indigo, among others) model would be its spatial facet. Colonialism had a certain culture of placemaking that seems to persist beyond political sovereignty or the abolition of slavery.

What were the principles sustaining this culture of placemaking? Even though colonisation was plural regarding nations, practices and timelines, Ferdinand argues that there was a consistent landscape management and planning mode. One of the principles was to consider that lands not managed by a representative of the colonising part were inherently "uninhabited" - disregarding the presence of indigenous peoples

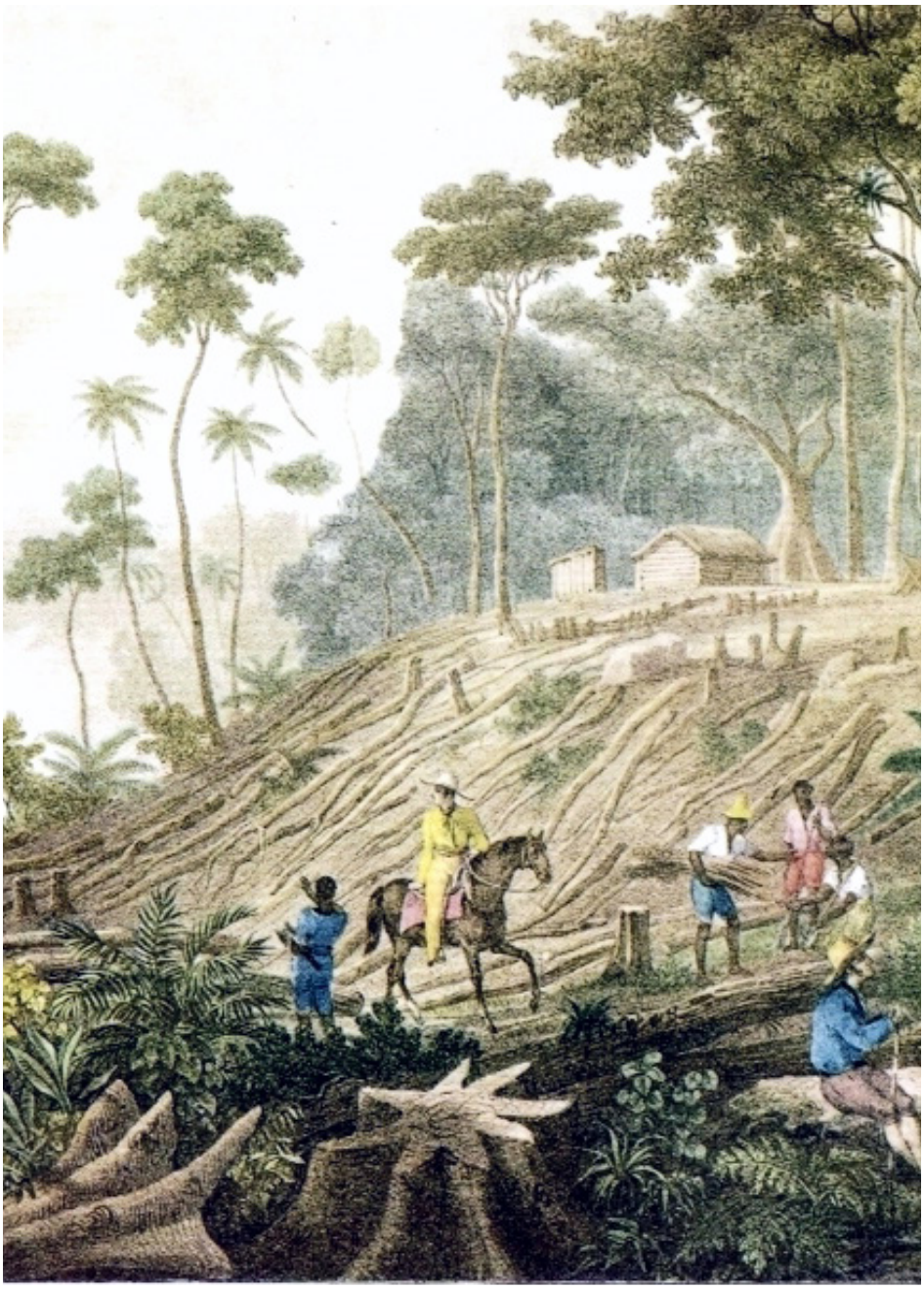


Fig. 06. “Devastation of the jungle”, paint by Johann Moriz Rugendas around 1820.

or fauna as forms of habitation -which called for clearing, deforestation and incorporation to the mesh of productive lands. Another principle was to assume that every land was available for commercial exploitation, justifying the intense drainage of the place's resources, human or non-human, such as the usurpation of soils. From this point of view, the world was reduced to a seemingly infinite assemblage of resources to be consumed, and the ecosystems, peoples, soils, and water were therefore commodified.
A third principle that can be highlighted is what Ferdinand calls "unequal ecological exchanges". In any undisturbed ecosystem, the flows of nutrients, energy and minerals are intrinsically circular, absorbed by living organisms and then reincorporated by soils by the time they die. However, in the colonial system, crops would absorb nutrients and water that would never be given back to those soils because such crops are exported. As is the case for many other aspects, it is a unilateral flow of values.

How did such principles become spatial - or, in potentially contentious words, what is the landscape architecture of colonialism? Colonial landscape management took physical form through private property, plantations and slavery. Private property was an unknown concept for the original Amerindian peoples. However, Portuguese settlers, for example, had the parcelling of land as their very form of occupation, creating a land ownership system which remains until nowadays and is of little dynamism. Such parcels would, then, be deforested and occupied by monoculture plantations, the primordial form of land use.

Aimé Césare, a politician and writer born in the French ultramarine province of Martinique, described in 1950 how the landscape looked like on the island and how the model was impacting people's lives: "I am dazzled by the amount of cotton or cocoa exported, hectares of olive trees or vines planted. I speak of natural economies, of harmonious and viable economies, of economies commensurate with the indigenous man being disorganised, of native food crops destroyed, of sprawled undernourishment, of agricultural development oriented according to the sole benefit of the metropolises, the intense flux of products, the intense flux of raw materials." (Translation by the author, original in French, cited in Ferdinand, 2021)

"It does not matter if we are talking about cotton, indigo, tobacco or sugar cane, the Plantation was the main form of land occupation (...) the establishment of these plantations as the way of dwelling in these islands structured the rest of the occupation of the wider territory as well. The construction of ports, roads, railways and even of parishes (religious divisions) was planned from the perspective of this colonial way of dwelling." (Translation by the author, original in French)

By making the spatial aspect of colonisation and its procedures more explicit, it becomes clearer how this process - rooted in erasure, deforestation, monocultures, exploitation and displacement of values - and the current environmental crisis can be linked in a cause/consequence manner. Inaugurated in 1492 with the arrival of European settlers in the Americas, this model has been globally reproduced ever since. The actuality of the issue is attested by the fact that scholars have been talking more and more about the world of plantations[01].

Acknowledging the interplay between colonialism and the present environmental situation is at the heart of discussions on the consistency of the term Anthropocene, coined by Paul Crutzer. The definition of this age is that "human industry has come to equal or even surpass the processes of geology", becoming the major force in the destruction of the planet as we

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01 The magazine produced by the University of Wisconsin-Madison, named Edge Effects, published a comprehensive compilation of material on the topic of plantations. Available on https://edgeeffects.net/plantationocene-series-plantation-worlds/ (accessed on the 22nd of February 2023)

Characteristics of Colonial Placemaking

	Principles	Foundations	Forms
Relationship to the soil	Geographical and ontological dependence	Usurpation of soil	Private ownership of the land
Relationship to non-humans	Exploitation of non-humans	Clearing and deforestation	Plantations
Relationship to other humans	Exploitation of non-humans	Massacre of Native Americans and domination of women	Servitude and slavery

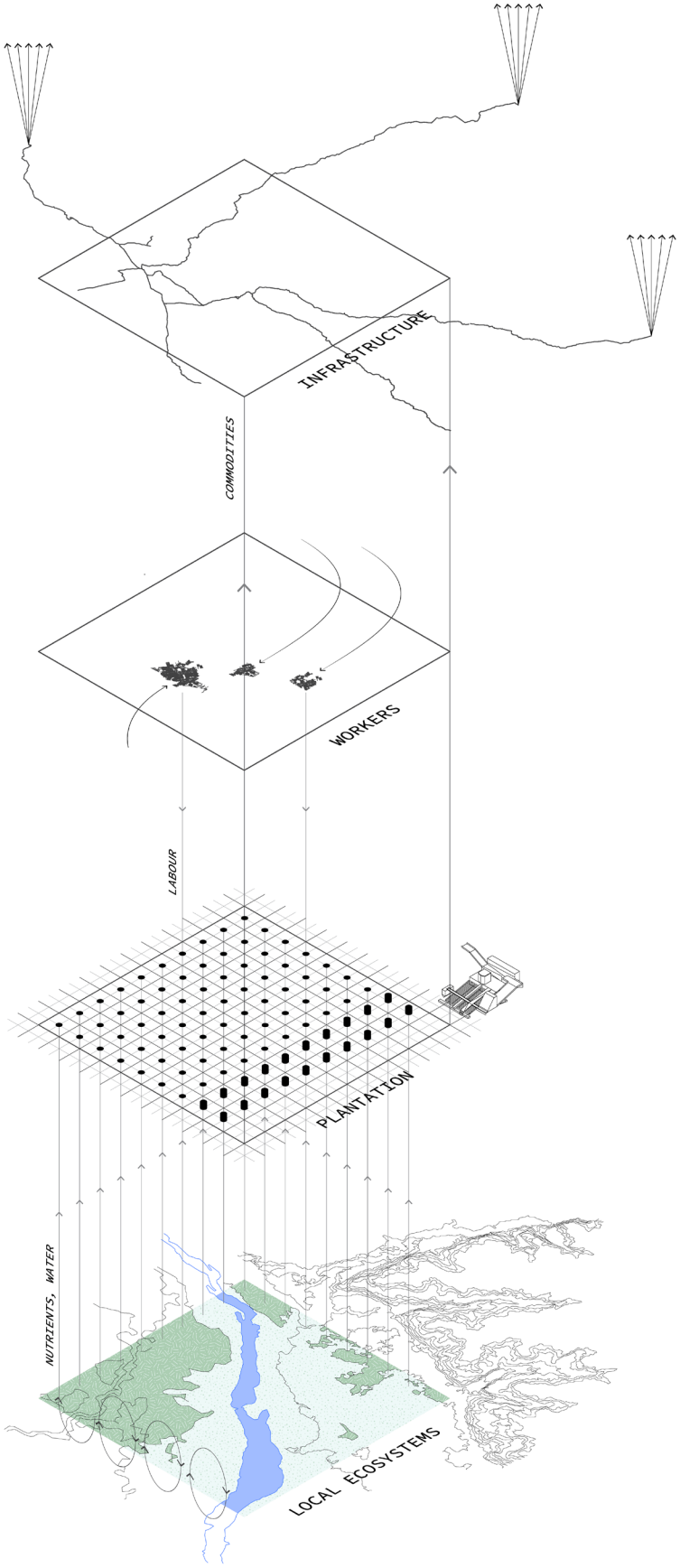
Based on Ferdinand, 2021.

know it. The term's existence is positive because it turns the extent of human alterations on global ecosystems known to a broader public. On the other hand, using the term Antropos implies that such a situation results from the intrinsic characteristics of humans as a species. The idea of it as a "species act", as Donna Haraway put it, overlooks all sorts of nuances in placemaking practices by different political, gender, and ethnic groups, to name a few examples.

Because of this lack of nuances, new terms to cope with such are in constant formulation. Not to invalidate the term Anthropocene but to add finer resolution to it. In 2014, a group of scholars in Environmental Humanities agreed on the term Plantationocene (Haraway et al., 2015). This term generally refers to the ecological loss linked to human-tended farms and all intensive agricultural land because it entails deforestation, ecosystem homogenisation and chemical pollution. Maybe differently from the term Anthropocene, the Plantationocene takes historical layers into account, situating the present situation in a historical continuum that would have begun by 1492 with the occupation of the Americas. Beyond the production/extraction site per se, the Plantationocene fosters a repetitive way of life, with uniformised plants and, therefore, ecosystems, which generates homogeneous ways of consumption, such as in fashion and food. So far, the idea of the Plantionocene was the main theoretical tool to understand why the Paraná River basin is as it is, its "raison d'être" and the underlying model that produced and still sustains it.

The formulation of a Plantationocene not only situates this model in history but also explains how it is an enduring cultural, economic and spatial legacy which continues to be applied and reproduced. Just like the colonial way of placemaking, the Plantationocene also has consistent principles and forms, as stated mainly by Donna Haraway and Anna Tsing (Haraway et al., 2015; Haraway, 2015). First of all, the logic of the Plantation entails a radical simplification of the existing local ecosystems, replacing complex webs of food and inter-species dependencies with hectares of cash crops. The fact that this erasure is not sustainable in the long term is not a problem in the logic of the Plantation because the priority lies on short-term yields and profits, even if such completely exhaust local resources.

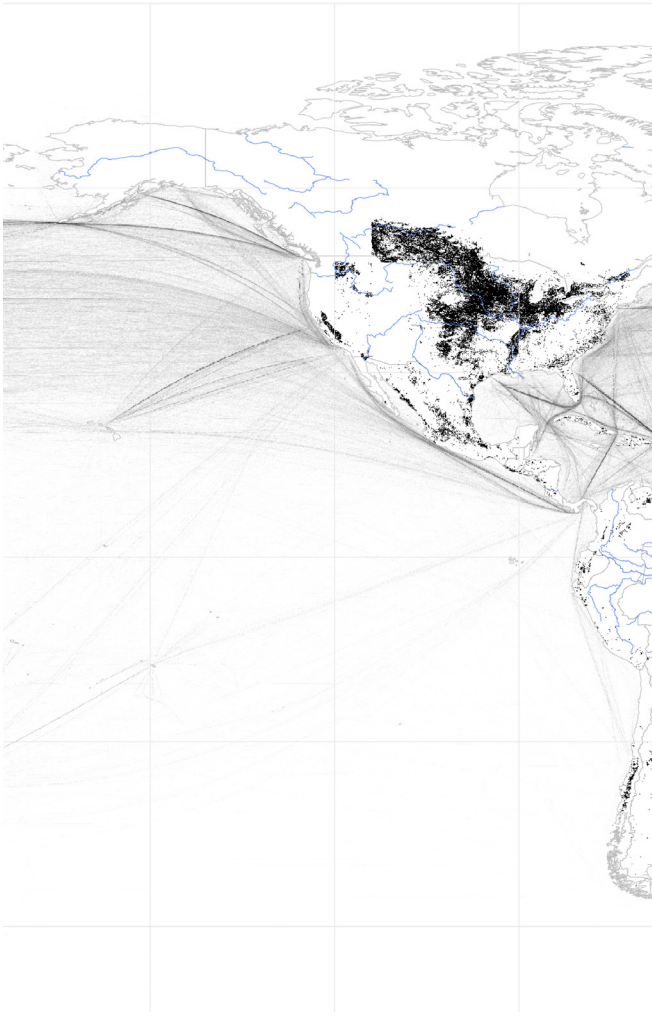
Secondly, the plantations require a deep discipline of people (workers) and plants. The most dramatic form of discipline is imposing harvest temporality on generational times. That means that everything is paced according to production timescapes. For example, in the Paraná River basin, the Eucalyptus forests for wood pulp production are completely cropped every 6 - 7 years, leaving completely exposed soils behind them. This



Layers and dynamics of Production Landscapes.

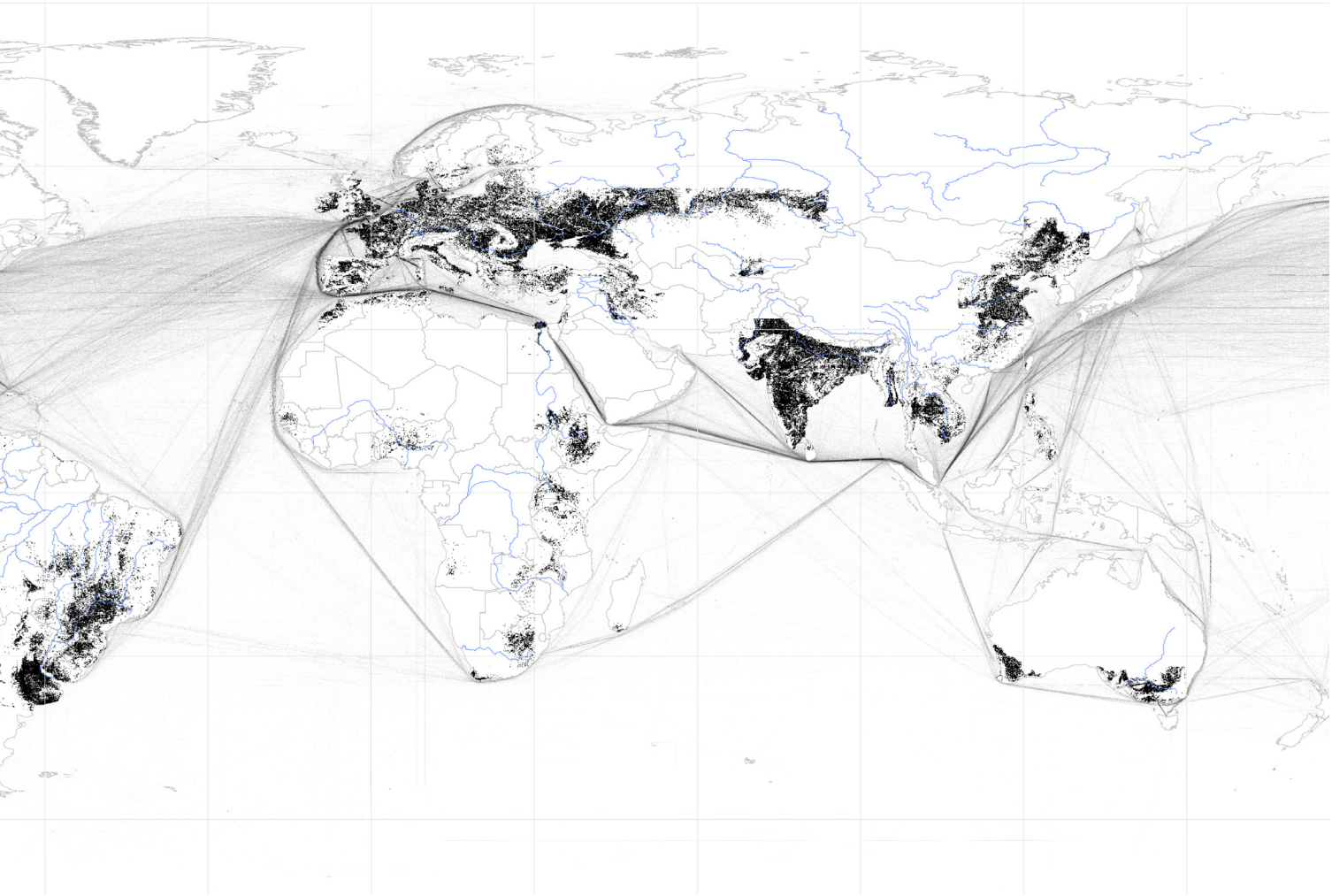
temporality is not paced according to the lifespan of a Eucalyptus tree, nor on the time a tree takes to absorb the most considerable amount of carbon dioxide, nor on the time soil takes to regenerate after nourishing a whole tree. It is the bare minimum amount of time to make the business profitable.

Thirdly, regarding spatial arrangement, an essential aspect of the Plantation is the imposition of a Euclidean grid on the world. "If you think about Euclidean geometry, the line has no width; a dot has no depth, no space, it does not exist. It is a mental construction," states Kenneth Olwig, Professor Emeritus of Landscape Planning at the Swedish University of Agricultural Sciences (Haraway et al., 2015). This abstract order is imposed on space as the physical manifestation of property. Then the other systems adapt to it: for example, drainage is adapted to have crops growing evenly in the whole property. The simplified landscape is then equipped with features that make exports easier (such as railways and ports) because Plantations are linked to the global market, also in terms of investments and land ownership.



Finally, Neil Brenner and Nikos Katsikis (2020) bring the notion of 'hinterlands of capitalism', which can help situate the idea of the Plantationocene in the web of contemporary financial relationships of power. The hinterlands of capitalism account for all the operational landscapes occupying almost 70% of the global surface. Such are in constant dialogue with the 2.5% occupied by urban areas, providing them with commodities, raw and processed materials, in a somewhat unequal metabolic exchange. They are forged to sustain the ever-ambitious supply chain of capitalism, even if such exposes local communities and ecologies to constant vulnerability, risk, and degradation - the ongoing drought event at the Paraná River basin is a good example of ambition-based mismanagement. The authors conclude by posing the essential question: "Can the massive socio-technical capacities it [this form of spatial organisation] has unleashed somehow be harnessed to support more just, democratic, nonviolent, culturally vibrant and ecologically sane forms of collective existence?".

Since the arrival of the first settlers around 1500, Brazil's role in the global economy has been marked by resource extractivism, commodity exportation and original biomes being steadily replaced by farms. Even though the country has been independent of the Portuguese crown for roughly 200 years, aspects of the colonial way of dwelling on Earth, such as the spatial model of the Plantation, are crystallised by history and therefore continue to be reproduced. However, there is a wish for change. For example, on the 6th of February of 2023, activist Marina Silva, Brazil's new Environmental minister, was interviewed by the British newspaper The Guardian, where she argued that this "rudimentary model of economic development" is no longer



Crop-production landscapes of the world.

viable[02]. According to this interview, the government would lean towards other sectors of the economy, such as creating skilled jobs and investing in technology. Agricultural yields could continue to grow through more advanced practices on the same area of cultivated land, holding deforestation back. Moreover, the recovery of degraded lands with native species would be rewarded with carbon credits.

Understanding the current land use of the Paraná River basin as the result of a model, a way of occupying and managing the landscape sustained by global supply chains, makes it approachable and understandable. It explains the intense transformation that happened during the period between the first expedition in 1905 and now. By the time the expedition happened, Brazil was no longer tied to the Portuguese crown. However, as mentioned above, the colonial way of dwelling on Earth remains in the Plantationocene as an enduring legacy of land management and placemaking, and parts of the history of this territory resonate with the principles stated by the scholars mentioned earlier. Another legacy that cannot be ignored is the rigidity of certain countries' roles in the global market, as noted by Jason Moore when developing the idea of "Cheap nature" in relation to the Global South (Moore, 2022).

Until 1905, most of the Paraná River Basin was still unexplored. The State of São Paulo, one of Brazil's federative units within which at least half of the basin is located, sent a group of explorers, the Geographical Commission, to map the land and its resources. As it will be commented later, this group's report shows that this expedition's main goal was to assess how economically profitable this territory could be. Extremely fast transformations marked the decades following their evaluation: railways were quickly built to 'colonise' the land, bringing waves of migrants and taking tons of coffee beans, the first widely planted culture in the region. Once the economic cycle was established, deforestation took a highly accelerated pace.

Fig. 07. Group of explorers about to leave for indigenous hunting and land demarcation.

By the time of the expedition, there were still indigenous populations living in the region, notably the Chavante, as described by their report (Comissão Geographica e Geologica do Estado de S. Paulo, 1911), and the Cayuás and Caingangues. Shortly after, two railway lines were built, the

02 https://www.theguardian.com/world/2023/feb/06/investigate-bolsonaro-for-genocide-says-brazils-marina-silva

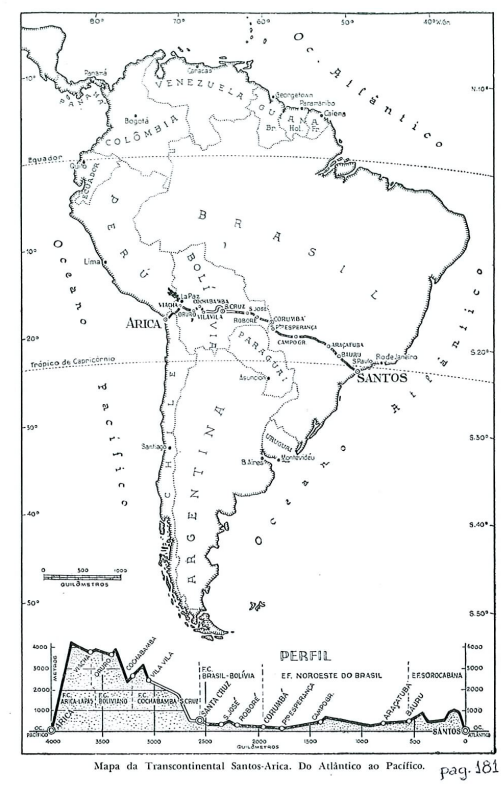


Fig. 08. The Noroeste do Brasil railway: a line crossing South America

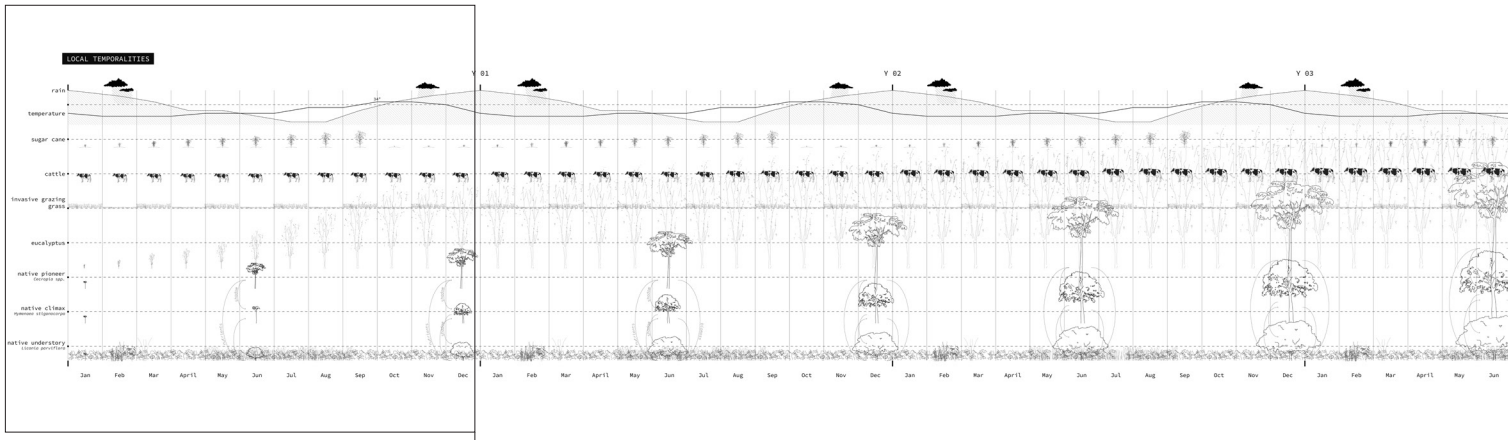
Fig. 09. Typical train stops built for the Sorocabana railway.

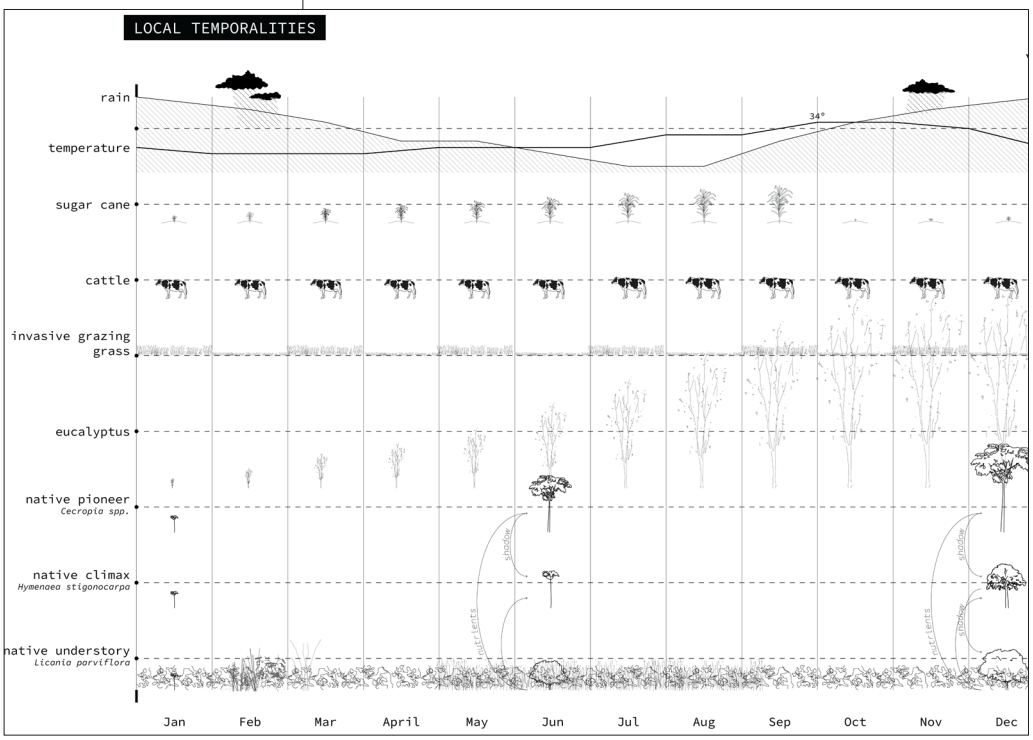
Sorocabana (1905) and the Noroeste (1906), which reached the Paraná River and connected the region to bigger cities and ports on the coast. The history of infrastructure in this territory really resonates with the definition of the simplified landscapes of the Plantationocene: the guideline for implantation is to make exports as straightforward as possible. As a consequence, besides the expansion of coffee plantations, violent territorial fights arose between the indigenous populations and the recently arrived landowners, which resulted in the semi-genocide of the first. The introduction of migrant labour, represented mostly by Japanese workers, was key to colonising the Paraná River basin. These populational waves came from Japan, supported by the Japanese government, as a way to cope with the unemployment crisis generated by industrialisation and the mechanisation of means of production and, later, by the Japanese-Russian war. In 1907, a representative of the Imperial Japanese Colonisation Company Kôkuko came to the state of São Paulo to assess the migratory possibilities and left after signing a contract where 3 000 people would be initially brought every year, with significative funding from the Japanese and São Paulo governments. Upon arrival, each family would be responsible for 1500 to 2000 coffee trees (Ocada, 2014).

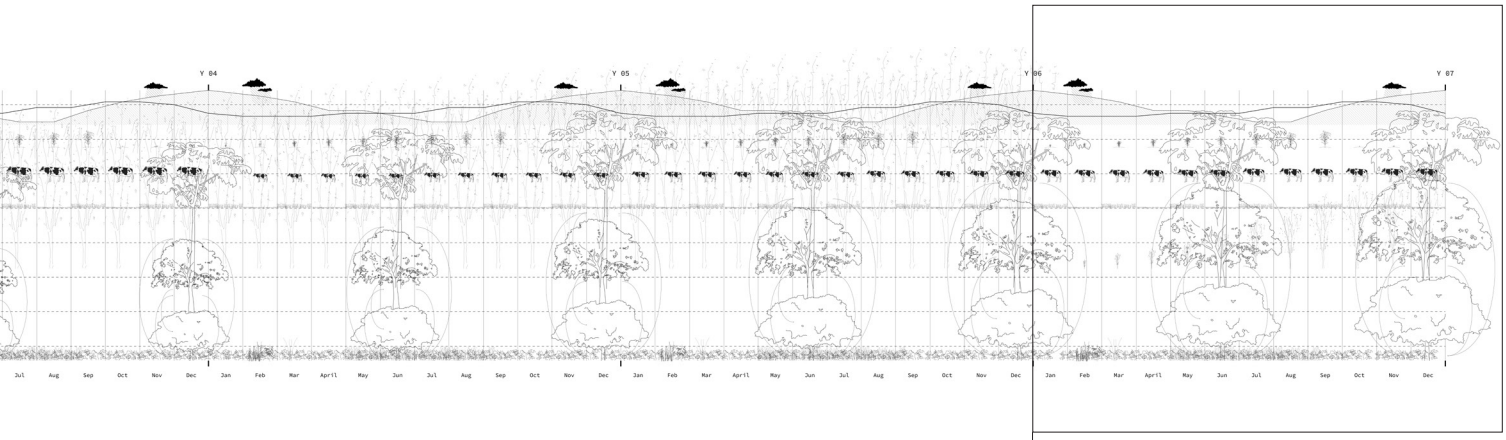
To conclude, the Paraná River basin underwent a process similar to many other locations in the world, constituted under the plantation model and its intrinsic modus operandi. The characteristics of landscapes generated by this model, including the Paraná region, are recognisable, to various extents, as the rationalisation of the territory in forms of occupation and infrastructure implementation, the tabula rasa way of planning, the introduction of external workers, the subjugation of local ecosystems, and unilateral flows of nutrients and goods.

COMPARISON: DEVELOPMENT OF HUMAN INDUSTRIES (SUGAR CANE, CATTLE, GRAZING GRASS, EUCALYPTUS) VERSUS NATIVE ECOSYSTEMS (PIONEER, CLIMAX, UNDERSTORY) OVER A 7-YEAR PERIOD

ESCALATING COMPLEXITY AND INTERDEPENDENCIES VERSUS “ETERNAL RETURN TO ZERO”.



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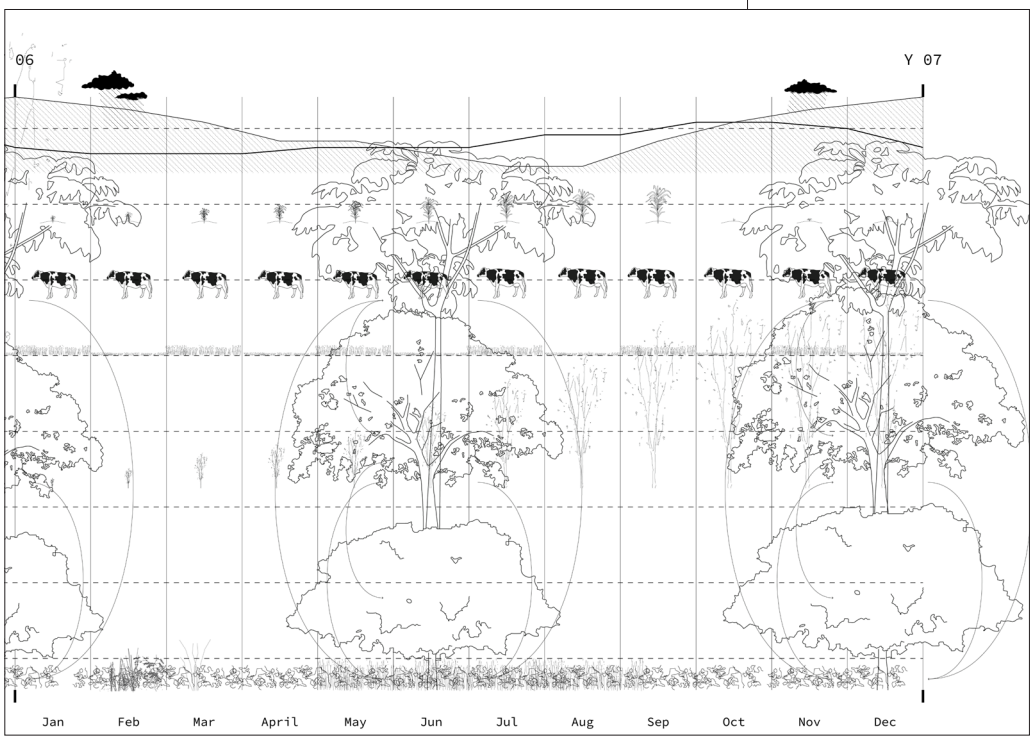
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“Back to zero”: an Eucalyptus field after harvest.

A truck especially designed for transporting Eucalyptus trunks in this terrain.

Sugar cane industry.

Cellulose processing plant.

02.05 The resulting landscape: study trip

Between December 2022 and January 2023, I had the opportunity to visit a small portion of the Paraná River. The research trip was funded by FAST Fund TU Delft, by the Fundatie van de Vrijvrouwe van Renswoude te Delft, and by the Phillip Spannenberg Travel Grant from the Urbanism Department at the Faculty of Architecture and the Built Environment. I visited the São Paulo State Archive twice, spent five days in the city of Três Lagoas, close to the Paraná River, and visited the Parque das Neblinas, a privately-funded park experimenting with ecosystem regeneration. A Travelogue has been produced after the trip, which can be found as an appendix to this thesis.

02.05.01 Findings at the São Paulo State Archive

The São Paulo State Archive has a precious collection of documents at a national scale, including documents from colonial times. About the Paraná River, they had precious maps already in digital version, depicting the process of occupation towards the westernmost border of the state (which is defined by the Paraná River itself), and the report produced by the Geographical Commission after their first exploration trip. The historical maps tell how this territory went from “unknown territory occupied by ferocious indigenous peoples”, as described in maps from the 17th and 19th centuries, to plantation landscapes cut by straightforward railways and infrastructure.

During 1905 and 1906, the Geographical Commission of the São Paulo State travelled along the Paraná River to map and catalogue it for future economic exploitation. They describe a broad river full of rapids, waterfalls and rocky formations. Geologist Guilherme Florence identified most of the stones as volcanic grey sandstone. There were also sandy islands formed by the intense sediment flows in the river, and the neighbouring trees showed traces of seasonal floods of up to 8 metres high. Besides that, the river was meandering, sometimes violent, sometimes calm, sometimes profound and sometimes shallow. The margins were fully vegetated with tall and imponent trees, and inland explorations reported the existence of marshlands after riparian strips of taller trees, which probably grew more because of the most fertile soils immediately adjacent to the Paraná River.

Meetings with Chavante indigenous peoples also occurred and were documented. Even though there was much fear from the side of the Geographic Commission, contact was usually friendly. Apart from direct interaction, the commission also reported on fires seen from afar (as the

indigenous burning practice commented above) and abandoned settlements, as most indigenous peoples in Southeastern Brazil were known to be nomadic.

The economic intentions can be read in en passant commentaries made in the report. João Cardoso, the Head of the Commission, wrote in the introduction that "this exploration comes to offer a powerful help to the development of this big region, allowing the state to choose certain points to be reached by railways, which will facilitate the settlement of this atrophied region [...] which will soon contribute to the progress of our nation" (translated from Portuguese by the author, extracted from Commissão Geographica e Geologica do Estado de S. Paulo, 1911). The geologist also included comments on areas favourable for cattle ranching in his report.
As a result of the visits to the São Paulo State Archive, the author traced the mapping made by the Geographical Commission to an AutoCAD format and typed the report's text into digital format. Both outcomes were offered to the State Archived as a form of gratitude for their willingness to help.

02.05.02 Stay at the margins of the Paraná River

03/01/2023 - A mosaic seen from the plane

As the aeroplane travelled towards the western part of the State of São Paulo, the model of the plantation was already visible, with its straight lines and organised mosaic pattern. Rivers were, as expected, choked between tiles, with proportionally little space for riparian vegetation. Once driving our rented car towards the city of Três Lagoas, where my mother and I would be staying, roads and other infrastructural elements were visibly aligned to the logic of the mosaics, consisting of straight lines to be lost in the horizon. The city of Três Lagoas itself was extremely sprawled, with very sparse houses and almost no verticalisation. It has roughly the same population as Delft (120 000 versus 101 000), but it is so widespread that one can drive a car for 30 minutes without crossing its urban borders.

It was the wet season, which meant that most of the 1247 annual millimetres of rain were navigating in the territory, either in the form of clouds or already closer to the soil. In Três Lagoas, many streets were flooded, leaving some houses inaccessible.

04/01/2023 - Eucalyptus, local fauna, local food

Our first entire day in Três Lagoas was mainly spent at a cellulose production plant and its neighbouring 1.4 million hectares of eucalyptus

plantations, which accounts for 650 000 seedlings produced yearly. This cellulose plant is among the biggest in the world and is responsible for around 10% of the global cellulose, 95% of which is exported.

A talk with agronomists that work there clarified their land management practices. First, they use a few different clones of eucalyptus, which are genetically enhanced to withstand a climate regime that would not be entirely ideal for them, and to generate wood pulp in a particular structure the industry wants. They try not to plant the same clone variety in neighbouring patches to offer living beings some variation in genetic diversity. Still, this is a non-natural situation where soil, insects and birds are disadvantaged. They also try to vary the age of each patch of the plantation so that neighbouring patches are not harvested at once, causing higher disturbance for fauna circulation.

Because of the significant amounts of rain between October and March, there are some techniques to slow water runoff and prevent topsoil erosion. For example, they always do contour planting, and ditches are dug along the roads. There are no water storing techniques, and during the dry season, all water used in the plantations comes from the nearby dam, carried in trucks equipped with hoses.

The transportation of the produced goods is very effective. There are trucks specially designed to carry eucalyptus trunks from the harvested fields to the cellulose plant; they are longer than any commercial truck to be found in the regular Brazilian market and can only operate within their property. Once processed, the cellulose is carried by truck to a railway stop belonging to the enterprise and then goes to the port city of Santos, towards the Atlantic Sea.

The rest of the day was spent in a park in Três Lagoas and at the evening market at the Central Market building. The park is one of the main open-air leisure places of the city, and what is most interesting about it are the several references to local native mammals and birds. Capybaras and anteaters were painted on local shops' walls, bins decorated as toucans, and statues of tuiuiús, a local giant bird. Such contrasted with the factory-like uncountable hectares of eucalyptus plantations we had just recently visited.

In plantation landscapes, there are not many people to be seen circulating; it is a human desert. However, the evening market was the first time in almost 24 hours that we could see several people together. The environment was lively, with the first half of the market selling local dishes and the second half selling locally sourced fruits, vegetables and artisanal

goods. It is the social heart of the city, which has a poignant lack of leisure areas - one worker in the eucalyptus industry told me she mostly spends her free time going to these concerts in the market or privately-owned bars.

05/01/2023 - Sugar cane

On the third day, we crossed the Paraná River and travelled along the other side of it on our way to the Aguapeí State Park. When looking at the land use maps I was tracing, it was already clear that while the eucalyptus industry occupies the right portion of the river, its left side is almost completely dominated by a mosaic of sugarcane plantations with punctual tiles of cattle ranching. However, seeing the extension of the sugar cane plantations in real life disappear on the horizon continued to be a very impressive experience.

We arrived at the Aguapeí State Park and were soon hosted by our guide Adriano. We first visited the margins of the Aguapeí River, which is one of the last tributaries of the Paraná to flow without any dams. It still has its meandering pattern, full of curves that get abandoned over time (a sedimentation process that forms the so-called horseshoe lakes). The park has been fighting with neighbouring cattle ranchers that lost access to the river when the park was established in 1998. They have been letting their cattle invade the park to drink water from the river, which causes many seedlings to be stepped on.

The park team has been experimenting with ecosystem regeneration, introducing pioneering species. They have, however, lost some battles against the Brachiaria grass, as mentioned earlier, which is an exotic species brought from Sub-Saharan Africa and dispersed around the central highlands of Brazil by cattle ranchers. This species of grass has the capacity to outcompete native species, causing seedlings to die because of a lack of water and nutrients. It grows extremely fast and can withstand the local harsh periods, reasons for why ranchers so widely use it.

Following the visit, we went to the margins of the Paraná River at the waterfront of a city called Panorama. It was interesting to see how the river can become the social heart of a small village, and there was a lot to be learnt about it in terms of leisure practices along the river. There were many bars serving beer and fish appetisers at outdoor tables. There were also many stalls selling local fish, which hinted at a relevant fishing culture connected to the Paraná River. A swimming zone was built with an artificial sand embankment simulating a beach, with umbrellas, palm trees, and a big slide. The atmosphere was vivacious.

06/01/2023 - Leisure by the river

The last day travelling around the Paraná River consisted of a visit to the local swimming area of Três Lagoas and to Guaraçaí, which is one of the cities created by the mass migration of workers towards the west of São Paulo.

The swimming area is located at Jupiá reservoir's margins, created by the local hydroelectric dam, Engenheiro Souza Dias. There, we could observe some samples of biotopes that form in the river's banks and the soft edges they create.

The visit to Guaraçaí was interesting because it narrated a social story of this landscape. Guaraçaí emerged as a city mostly because of the waves of Japanese migrants settling in western São Paulo, to work on the coffee plantations. This crop preceded the currently dominant sugar cane. We could visit the train station that was built as part of the infrastructural effort to bring people to this region - already announced in the Geographic Commission's report from 1905. The city had an atmosphere of economic and social stagnation.

02.04.03 Ecosystem regeneration: Parque das Neblinas

10/01/2023

The Neblinas Park is 7 000 hectares of a nature reserve, previously owned by a cellulose industry and now privately funded for research on ecosystem regeneration. It is interesting as a case study because it consists mostly of abandoned eucalyptus plantations: here, the regeneration effort was to let go of any management. The seed bank slowly took over, and now there are Atlantic Forest patches in many recovery stages. There was also a sharp increase in flora and fauna and water availability in the watershed of the relevant Itatinga River.

02.05.04 Conclusion

As a conclusion to the trip, a general picture of the Paraná River Basin could be grasped. It is a territory of impressive rationalisation and production-oriented operationalisation, which can be attested to in its spatial organisation, infrastructural lines, inhabitants and the stories they tell. When visiting there, it is hard to get in touch with local fauna and flora because of the ubiquity and extension of the plantations. On the other hand, there are points of inspiration, such as the Aguapeí State Park or the Neblinas Park,

where it is possible to experience native biomes, even in a geographically concise manner.

Back to the issue of drought, there were no dry places because it was the wet season, which also showed how wetness in this landscape gets completely omnipresent — at first, visiting the river when everything was so wet felt pointless, considering the research's interest in drought. However, it was soon proven to be of essential interest, for it was clear how water would circulate in plantation sites without no retention, causing soil erosion, floods in the cities, and no long-term management perspective (such as storing water to prepare for the dry season).

COLLECTING NATURAL AND CULTURAL LAYERS OF THE LANDSCAPE

Eucalyptus leaves

and bark

Sugar cane thicket

Brachiaria grass, used to feed cattle.

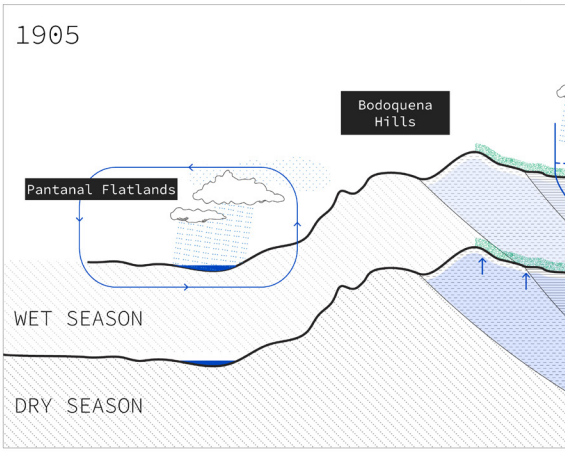

CARTE GÉNÉRALE DE L'ÉTAT DE
SÃO PAULO
avec indications sur l'Agriculture, le Commerce,
l'Instruction Publique, l'Industrie et la Colonisation
Dressée par la
Commission Géographique et Géologique
de São Paulo
Ingénieur en Chef, João Pedro Cardoso
Echelle 1/2.000.000
1910
MINAS
MATTO GROSSO
PARANÁ
Rio Grande
Rio Paranapanema
BARRETOS
S. JOSÉ DO RIO PRETO
BEBEDOURO
MATTO
TAQUARITINGA
IBITINGA
ARARAQUARA
BARIRY
BAURU
JAHU
AGUDOS
CAMPOS NOVOS
LENGOES
S. MANOEL
BOTUCATU
AVARÉ
PIRAJU
FARTURA
TAGUARANÇA
CAPÃO BONITO
TAXINA
CURITYBA
ANTONINA
CONVENTIONS :
Chemins de Fer :
São Paulo Railway
Comp. Paulista de Es de Ferro
Comp. Mogyana de Es de Ferro
E. de Ferro Central do Brasil
E. de F. Sorocabana Railway
E. de F. Noroeste do Brasil
E. de F. de Araraquara
E. de Ferro do Dourado
Estrada de Ferro S. Paulo e Minas
E. de F. S. P. e Goyaz
Brasilian Railway
Est. de F. Funilense
Diverses Comps
Eau Canalisée. Réseau d'Égouts. Illumination Électrique. Groupe Scolaire. Poste Météorologique. Diverses Industries.
Diverses Industries.
Poste Météorologique
Groupe Scolaire.
Groupe Scolaire. Illumination Électrique. Poste Météorologique. Diverses Industries.
Poste Météorologique. Diverses Industries.
Illumination Électrique. Diverses Industries.
Groupe Scolaire.
Poste Météorologique.
Petite Industrie.
Groupe Scolaire. Petite Industrie.
Illumination Électrique. Poste Météorologique.
Illumination Électrique.
Groupe Scolaire. Poste Météorologique.
Poste Météorologique.
Nucleo (colonies) Colonial.
Grand Centre Industriel.
Réseau Téléphonique.
Centres Industriels de 1es, 2e, 3e et 4e classe.
Forêts
Champs
Cultures des cafés
de la canne à sucre
du riz
du coton
diverses

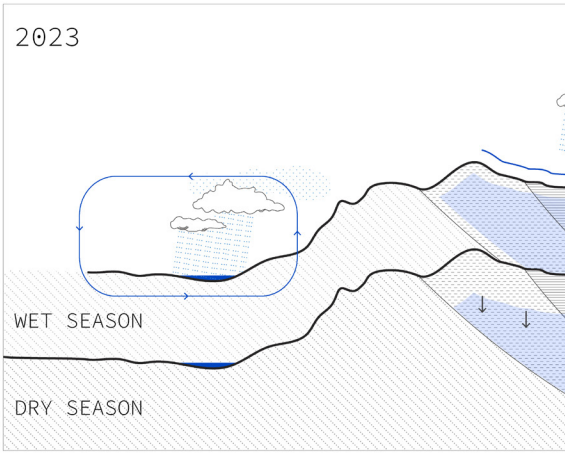

Mouvement du Port de Santos
en 1909
(Commerce International)
Exportation
Importation
VOIES DE NAVIGATION ENTRE
L'EUROPE ET L'ETAT DE S. PAULO (BRÉSIL.)
Edition du
COMMISSARIAT GÉNÉRAL
DU GOUVERNEMENT DE
SÃO PAULO DES
ETATS UNIS DU BRÉSIL
BRUXELLES
S. PAULO
SANTOS
CAMPINAS
RIO DE JANEIRO
OCEAN ATLANTIQUE
Production du café dans les districts les plus importants
Production du café en millions de kilogrammes.
EXPORTATION DU CAFÉ
POUR L'ANNÉE 1909-1910
EN BALLES DE 60 KILOGR.S
BRÉSIL
AUTRES PAYS PRODUCTEURS

02.06 Conclusion:
The resulting hydrologic system

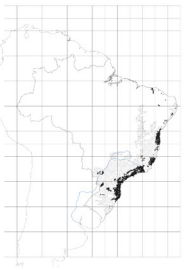
This chapter began by analysing the water retention capacity of the main types of land use in the Paraná River basin, concluding that such primarily do not present significant positive qualities. Extensive monoculture, cattle ranching and sprawled urbanisation are interfering with deep rainwater infiltration, undermining aquifer recharge, disturbing rivers and streams, and contributing to the decline of local ecosystems. All of which increase vulnerability to drought.

It is possible to affirm that the water cycle is disrupted. The Guarani Aquifer used to be a renewable and stable system but is currently dropping 2 metres yearly. Furthermore, Lee et al. (2018) proved, through historical data and simulations, the increases in the annual discharge of the Paraná River can be attributed to deforestation and the expansion of intensive agriculture. Considering the characteristics of the land use, the hypothesis this thesis puts forward is that the little water retention capacity of the plantation model is causing rainfall to be quickly flushed through the basin, replacing the original long times of infiltration and storage in aquifers, lakes and marshlands. The goal is to restore the hydrologic cycle by enhancing the time of water residency, or "sponge capacity".



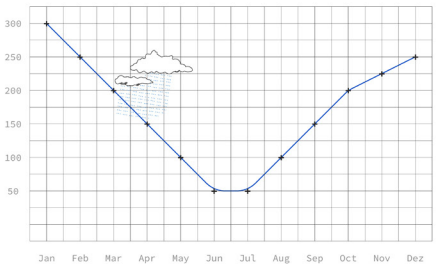


Forest in 2023

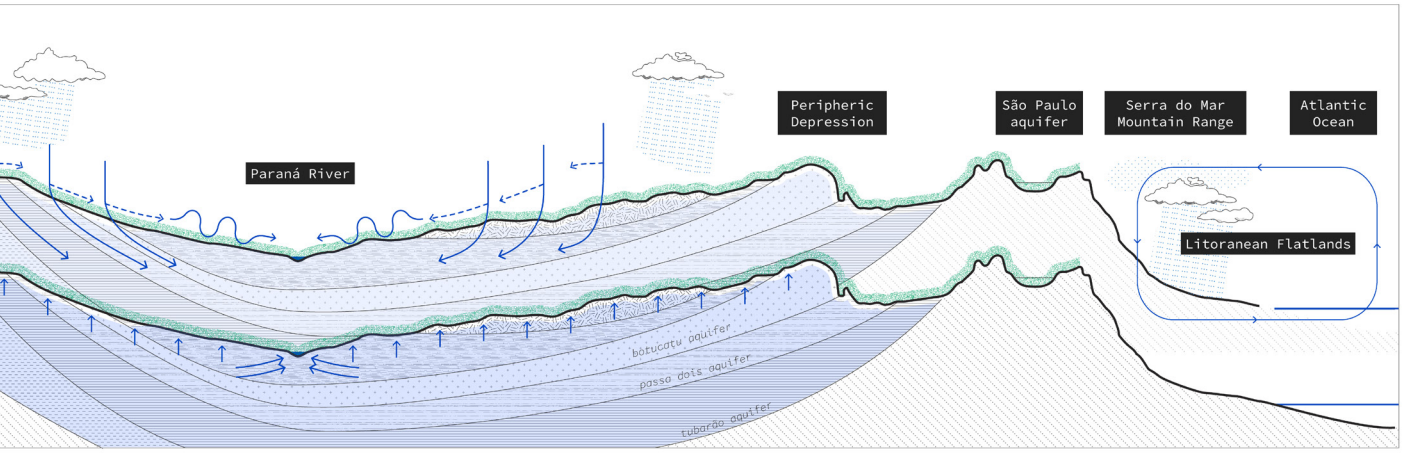


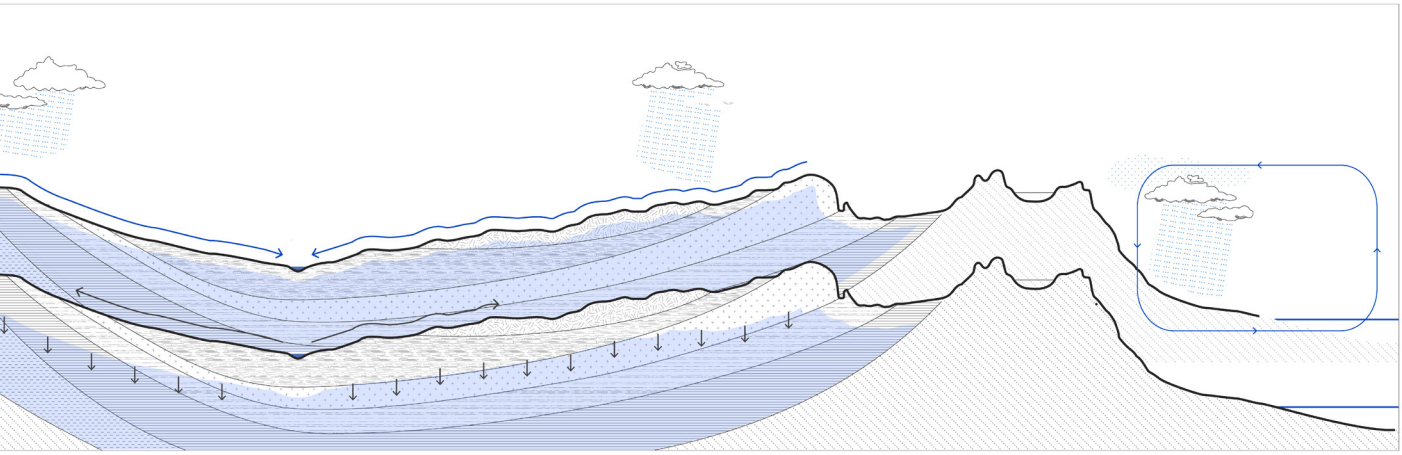
Drought in 2019

Wet/Dry season



Classification: subtropical humid with a dry season during winter (Cwa, Koeppen system)
Average annual rainfall: 1247mm





03. Regenerating the Hydrologic Cycle

03.01 Introduction

Spatial design as a disciple can shape the physical aspect of our surroundings, which steers social, cultural, political and economic aspects and gets steered by them dialectically. No design proposal is devoid of an initial ideology, set of references or intentions, nor unaccountable for the developments caused by its spatial transformations. To tackle an issue as broad as drought, a certain epistemological position needs to be defined first, the theoretical lens that will serve as the foundation for more operative actions, binding them as an ontologically consistent whole.

03.02 Principles

Principle 01. Slow and store: Mitigating the impacts of deforestation

Main literature:
Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. In Landscape and Urban Planning (Vol. 100, Issue 4, pp. 341–343). Elsevier BV. https://doi.org/10.1016/j.landurbplan.2011.02.021
Sponsland. Reis door het landschap van de toekomst. (2022).

The first principle departs from the belief that there is a disruption in the hydrological cycle that can be addressed through landscape planning. However, what is the baseline equilibrium that should be sought? Jack Ahern (2011) discusses a shift in the concept of sustainability, going from the image of perfect and long-lasting equilibrium inherent to natural systems to the adoption of the non-equilibrium theory. The non-equilibrium paradigm emerged in the second half of the 20th century. It stated that natural and cultural systems are variable and prone to constant and unexpected change (Botkin, 1990, cited in Ahern, 2011).

Slowly but steadily, the fields of Landscape Architecture, Planning and Urbanism adopted this shift in the sustainability paradigm and started to work with the idea of resiliency. The definition of resilience stands for "the capacity of a system to respond to change or disturbance without changing its basic state" (Walker & Salt, 2006). In spatial design disciplines, this comes as the idea that a region is "safe to fail"; that is, it can undergo extreme events and respond to them without experiencing disruption. Therefore, the answer to the previously posed question would evoke adaptive baselines instead of rigid, idealised ones.

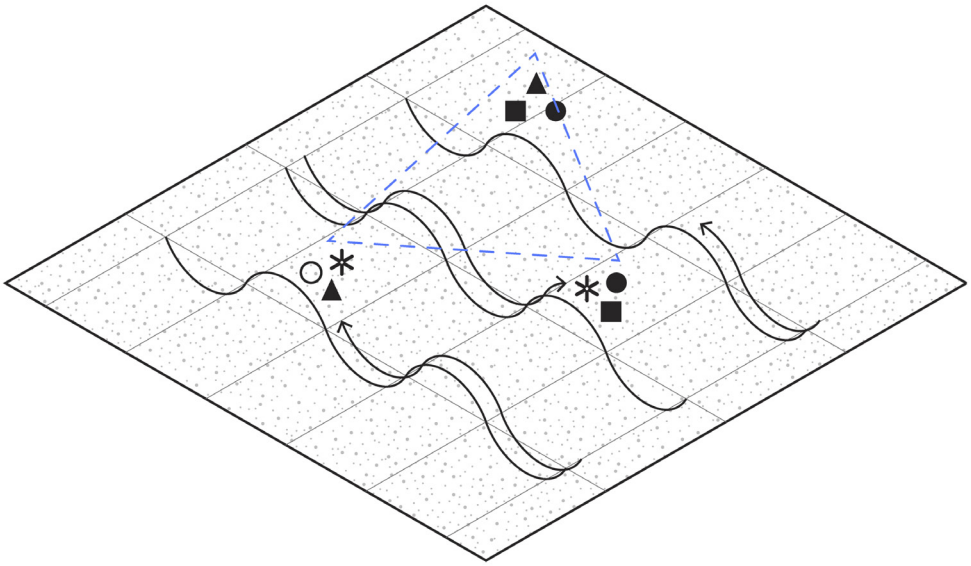
According to Ahern, it is also desirable that a landscape can support its human and non-human components while the disturbance is happening. For example, in the case of the Paraná River Basin, what happens to the local inhabitants during a low period in the global commodity market? Do they get unemployed? Moreover, what about global disruptions in the food supply chain as the United Kingdom is currently experiencing - what can a sugar cane-producing landscape provide? In the case of lack of precipitation, where can humans and non-humans, whole ecosystems, get water from? This thesis aims to address the vulnerabilities of this landscape and ultimately prepare it to experience the more intense and frequent disturbances connected to anthropogenic climate change. Therefore, a new baseline would go beyond tackling a specific threat (such as drought) and prepare the landscape that supports its living inhabitants to endure the disturbing event.

Ahern developed some guidelines to orient works in regional planning and design. Briefly, each location should be composed of diverse groupings of functions (multifunctionality), which are also performed by other locations (redundancy). Ideally, all these locations are articulated by a network of easy connectivity, which facilitates the circulation of entities (such as animals and plants) necessary for a landscape's functioning. Biodiversity is important for resilience because different species can withstand different magnitudes and types of disturbance. Hence, the recovery of a certain ecosystem becomes easier, and its complete decay becomes more unlikely. Finally, the non-equilibrium theory implies that every system is exposed to uncertainty, so spatial frameworks of performative locations should be thought of in a way they can adapt to new circumstances (adaptive planning and design).

Every regeneration process involves choosing what baseline is sought. If, in this case, the baseline sought is rooted in resilience and adaptability, the essential idea is that the hydrological cycle should be regenerated based on a resilience point of view. The way such can be spatially achieved might be clarified through case studies produced by contemporary Landscape Architecture practices working on climate adaptation.

Climate adaptation projects are being led worldwide, and it takes work to choose an example. To keep it within the Netherlands: the Global Summit on Climate Adaptation, which took place in 2021, the municipality of Groningen commissioned a few landscape architecture practices to come up with visions to address the dryer summers and the wetter winters the city has been experiencing. Gathered under the title of Sponsland, the output from this collaboration brings the idea of climate adaptation based on uncertainty and proposes the idea of a "Sponge City" inspired by the Chinese Sponge City policy. The essence is that landscapes with good water retention capacity can store water during wet periods, avoiding floods, and make this water available during the dry months, sustaining their existing dynamics. For example, the Dutch practice Bureau B+B envisioned a "Water Battery" to prepare the region for dryer summers and higher sea levels, avoiding peat oxidation and ensuring freshwater supply. The main strategy is to recharge groundwater during the wet winter months through a system of water retention features in urban and rural areas, storing a surplus for dryer summers and fostering water independence from the uncertain IJsselmeer.

Fig. 11



Principle 02. 'Acknowledge and restore interdependencies in the landscape' (a multi-species approach to hydrologic disruption)

Main literature:
Da Cunha, D. (2018). The invention of rivers. Baltimore, MD: University of Pennsylvania Press.
Escobar, A. (2018). Designs for the pluriverse. Durham, NC: Duke University Press.
Bellacasa, M. P. D. L. (2021). Soil Times: The Pace of Ecological Care. In Jaque, A., Verzier, M. O., Pietroiusti, L. (Ed.), More-than-Human (pp. 396-429). Netherlands: Het Nieuwe Instituut.

The change of paradigm initiated by the idea of resilient landscapes hints at the idea that addressing climate adaptation needs to go beyond resolving punctual technical tasks. In the case of drought, for example, the quest for resilience is more complex than implementing water storage compartments in the watershed because such would not prevent the decay of human and more-than-human ecosystems during disturbing events. Actually, a strictly technical solution to drought is somehow already in place since the numerous hydroelectric dams along the Paraná River already work as water storage compartments from which all industries get water during the dry season. The malfunctioning of this system gets more and more visible as one moves downstream: water availability decreases dam after dam, getting critical in the southern part of the Upper Basin.

The construction of resilience in the water regime of a landscape might need a re-interpretation of rivers and watersheds themselves. Dilip Da Cunha (2018) proposes a radically different view on these features. His investigation of how the Ganges River has been historically formulated, from a cultural perspective, as a line in the landscape made explicit the origins and limitations of this universally adopted idea of rivers. Many factors, spanning from cartographic conventions to colonial land management, implemented the idea that water springs are points and rivers are lines originating from them. According to this view, such a line is a sharp division between land and water, and this dualism should be preferably kept: the moving of such a line is either a flood or a drought event, both to be avoided and regarded as disequilibrium. Both are to be dealt with cisterns, dams, walls, concrete, and many other engineering infrastructures. According to this view, a river, which is the cumulation of other lines coming together (the tributaries), should be a static line, providing the surrounding land with drainage and water resources at an established pace and measure. The Paraná River, as it is now, is a product of this mindset, with its dams and artificially controlled water fluctuations, an engineered and instrumentalised line.

Once Da Cunha traced how the currently dominant idea of rivers has been culturally built, there can be both distance and room for new understandings of riverine matters. The perspective presented by Da Cunha and adopted here is not a reinvention of the wheel; on the contrary, it is a resumption of basic knowledge of the hydrological cycle taught even at schools but has yet to be applied in spatial planning. The fact is that the idea of a river as a line disregards most of the hydrological cycle: most of the flowing water humans can see in a river comes from rainfall, not from the water spring, and much of it does not flow directly into the river but can be stored in aquifers and other features for any duration from a year to a geological era. Across a watershed, water is present in clouds, humidity, mist, rain and all kinds of moisture-trapping pores in soils, buildings, materials, and living beings. The flows humans can see with the naked eye in rivers are a small, and very often the final, part of the water within the watershed. Da Cunha builds on the sketch of the hydrologic cycle made by Swiss-German artist Paul Klee to suggest that society has "cast anchor" to a fourth of it, which he calls "the time of reality". In contrast, the other three, named "moments of ephemerality" and consisting of the blurry sights of wet seasons, are largely disregarded. All maps, properties, infrastructure, and future visions would be drawn following this short state of affairs, which generates the issues society witnesses every year in an escalating manner, and calls for new understandings taking the other three-thirds of Klee's wheel into account.
A possible new view on riverine systems is the substitution of lines by gradients of, using the words of Da Cunha, "ubiquitous wetness". The essential shift brought by this notion is that the entire watershed is then encompassed; water availability is not a matter of lines but of areas (the landscape) and volumes (the landscape with its vertical layers, such as aquifers and clouds). Accepting the blurriness of water presence consists of a significant expansion of the actors and entities involved, for it implies looking at all the agents involved in every water process of the landscape (e.g. aquifer recharge and seepage, water retention, mist and moist retention).

The study trip for this project took place in January 2023, during the wet season. The Paraná River stricto sensu was a stable "line" in the landscape, with its artificially controlled levels. However, water, which is what actually matters in this discussion, was absolutely everywhere. The air was humid, a tapestry-like formation of clouds occupied the sky, and the horizon was smudged by mist. Water rapids were going down the topography everywhere in the sugar cane or eucalyptus fields; small floods were happening on the asphalt of Três Lagoas (the biggest city immediately along the Paraná River); the dams were quite full. Water was indeed ubiquitous; it was present in all the objects collected on site (stones, soils, plants), which were all wet

and cold to the touch.

As stated above, the idea of ubiquitous wetness causes a shift of attention from a line ("a river") to the whole area of the watershed in its entire volume (that is, taking its vertical layers, such as soils and aquifers, into consideration). This shift, in its turn, leads to a virtually infinite expansion in the chain of actors acknowledged to be involved in the hydrologic cycle. This seemingly infinite array of actors from different species and taxonomic kingdoms, come together in space, and spatial design is the human domain which creates more or less beneficial situations for them, in terms of what physical space can actually offer or deprive. Thus, Interdependencies and Ecological Care concepts are believed to be essential for drought prevention to become more than a purely technical, spatially punctual, assignment.

Arturo Escobar (2018) connects extractive globalisation to the disruption of local webs of relations, which leads to a lack of local autonomy. The Upper Paraná River Basin can be used as an example to explain what Escobar means: the substitution of local ecosystems by plantations (of sugar cane, of eucalyptus) erased the relations that the local fauna carried with them, eventually causing a decline in their populations, consequently making it harder for native trees to get their seeds dispersed by birds. Another example would be related to, using the words of Malcom Ferdinand (2021), "unequal flows of nutrients", where the above mentioned mono-crops take excessive amounts of nutrients from the soil without ever replacing them, simply because they got harvested and exported. This would lead to the decline of soil life and its capacity to retain water, contributing to drought and the disruption of local autonomy of the hydrologic cycle. Local webs of relations are mutually enhancing and cyclical, whereas extractive globalisation is unidirectional. Spatial design should do what it can to restore, or to facilitate instead of hinder these webs.

Many scholars in the fields of ecology and the social sciences have been advocating for the principle of the interconnectedness of life as a necessary ontological shift to deal with the exhaustion of the current system, made explicit by anthropogenic climate change and its associated reasons and consequences. Arturo Escobar writes: "All living, human or not, takes place within a relational matrix. The forgetting of this fact led to the development of patriarchal [aggressive, repressive, controlling] cultures". The idea that ecosystems have inherent inter-relationalities is not new, since it has been posited already by Charles Darwin (1859) and, some decades ago, reaffirmed by the Conservation Ecology movement (Soulé, 1985). Nowadays this idea re-emerges in circles of scholars in feminism, decolonialism, degrowth and critical analysis of modernity in general. Such modernity, represented by

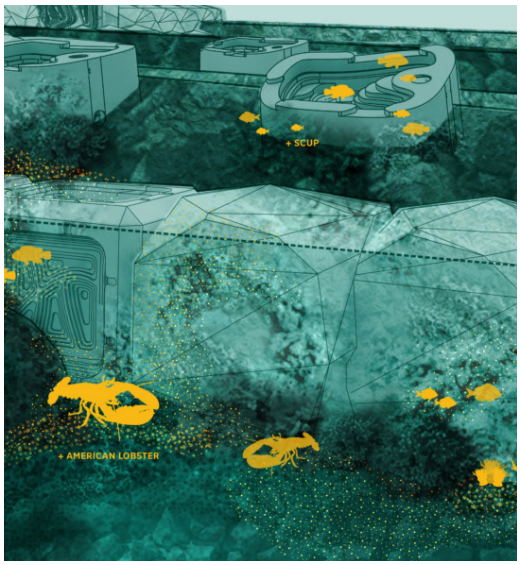


Fig. 12

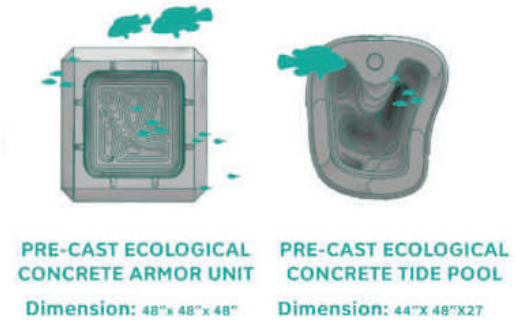


Fig. 13

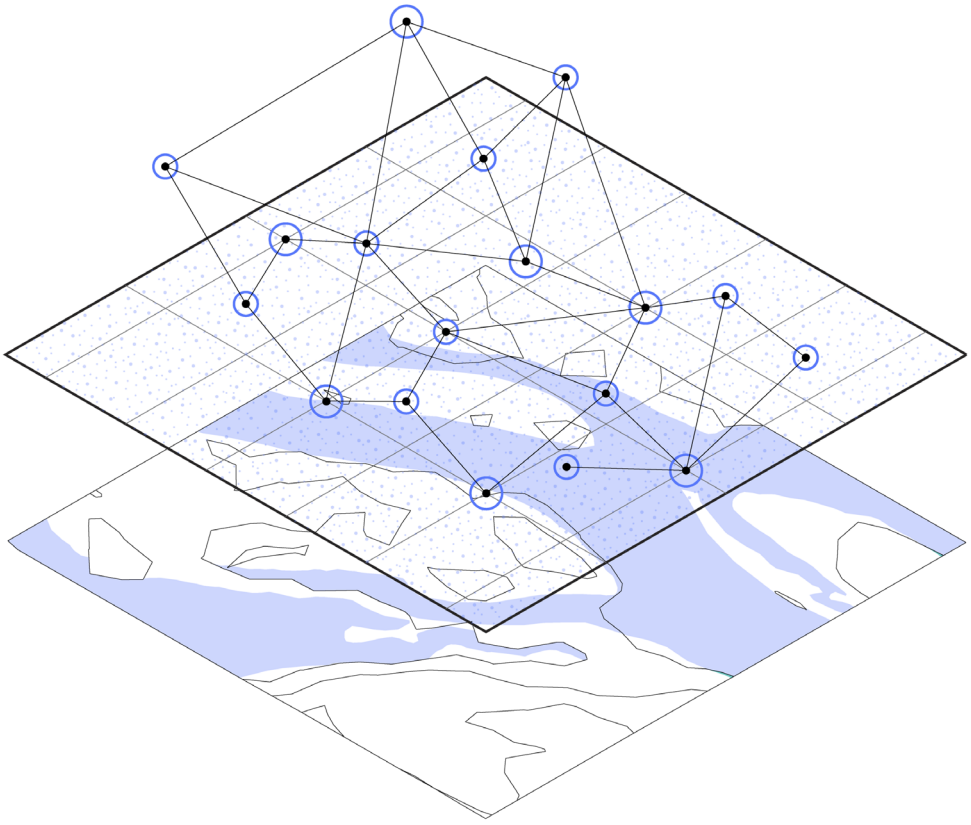
Rationalism and Cartesian tradition (Escobar, 2018) is believed to be strongly rooted in the modus operandi that led to, among other consequences, the present ecological crisis. In short, Rationalism and Cartesianism are deeply founded on the principle of scientific objectivity, which created the division between the observer (the individual) and the world. This dualism developed into the separations nature/culture, West/non-West, civilised/savages (which led to the "colonial divide"), subject/object (Latour 1993, cited in Escobar 2018). A growing field of authors argue that the activation of the notion of Relationalities is a possible way to dissolve such present dualisms (maybe especially the nature/culture one), spreading the understanding of the principle of interconnectedness combined with the biology concept of relationality, which states that beings are not only interdependent, but also mutually constituted (Sharma, 2015, cited in Escobar, 2018). Building upon the statement that spatial designers should facilitate such relationalities: can spatial design not only facilitate, but also favour relationalities to happen? If so, how can that happen?

The idea of ecological care can bring alternative relationalities between humans and the rest of the interspecies living world. María Puig de la Bellacasa (2021) explores this concept from the perspective of soils, as this living world has been artificially paced according to human markets since the times of the Industrial Revolution, and is now perceived as a finite resource (in human time scales). She characterises ecological care as the "mundane doings of maintenance and repair that sustain everyday life", as a broadened perspective where all species are constantly performing acts of mutual-constitution, sustaining a series of worlds in the making. To take the example of soil: an underground universe inhabited by uncountable species that not only get their nutrients from the dark matter surrounding them, but are equally responsible for its production and maintenance. The problem is that humans have occupied an outsider's position in this web of acts of maintenance, using technology to subdue soil fertility (or any ecosystem, but let's stick to the soil example) to their needs, feeding litres of fertilisers without attention to wider ecological effects, while abstaining from the making of this world (unidirectional relationality). Plantation landscapes are a clear example of this.

Another example is the constantly debated idea of "ecosystem services" used by many planners, which implies that ecosystems are valuable because they have something to offer humans (e.g. clean air, clean water, beauty). A serious level of relationality to deal with the ongoing Anthropocene crisis calls for the ontological re-insertion of humans in webs of ecological care. One example that María Puig de la Bellacasa gives is related to temporalities: different actors of the landscape have different temporal

needs (e.g. the pace of soil regeneration is not the same as the pace of cellulose production), and multi-species ecological well-being depends of re-aligning and respecting such different rhythms.

The second principle, "Acknowledge and restore interdependencies in the landscape", is about looking at the problem of drought, of disrupted water cycles, not as a technical problem to be solved from an engineering perspective, but as a broad problem that is connected to all the living entities within the Upper Paraná River Basin. Dilip da Cunha expands our understanding of rivers not as lines in the territory but as systems of ubiquitous watershed-wide wetness, which entails that soil, vegetation and animals are also part of it. Arturo Escobar defines the current ethos of human attitude towards ecology (domination, extraction, nature/culture divide), and introduces the acknowledgement of relationalities as a step to dissolve such dualisms and build alternative futures. The idea of ecological care explored by María Puig de la Bellacasa gives shape as to how the principle of relationalities can exist as a human act. In a nutshell, it would be beautiful to say that tackling the issue of hydrologic disruption is also an opportunity to enhance the territory in a multi-species perspective; however, calling it an opportunity is an understatement: to properly address this issue, a non-anthropocentric approach is more like an obligation, an unavoidable assignment.



Principle 03. ‘Enable negotiation between economy and ecology.’

Main literature:

Sijmons, D. (1991). Het Casco-concept: een Benaderingswijze voor Landschapsplanning, (IKC-NBLF, Utrecht)

McHargh, I. (1969). Design with Nature.

Nijhuis, S. (2022). Landscape-Based Urbanism: Cultivating Urban Landscapes Through Design. In: Roggema, R. (eds) Design for Regenerative Cities and Landscapes. Contemporary Urban Design Thinking. Springer, Cham. https://doi.org/10.1007/978-3-030-97023-9_11

An adaptive framework that can withstand disturbances and considers the importance of multispecies well-being, which becomes one of its strengths in coping with events such as drought. The idea of a framework of performative spaces was already present in the “Casco-concept” formulated by H+N+S Landscape Architects (Sijmons, 1991), and was considered successful in creating more resilient landscapes, distinguishing the areas in which slow ecological processes can happen from the “user space”, anthropocentric developments with more accelerated rhythms, generally consisting of the infrastructure and occupation layers. In 2023, this concept was revised with the Urbanism department of TU Delft, arguing for including a negotiation space around the framework.

A negotiation space, or “buffer”, between the framework and the “user space” comes at a moment where it is already clear that the last pressures the previous, be it because of noise, pollution, and real estate matters or because of the lack of more gradient-like transitions, weakening the framework by processes such as the edge effect. The negotiation space aims to strengthen and protect the framework by adding a gradient layer where ecological and economic processes should come together and find a common collaborative ground. Ultimately, when a mutually advantageous state is reached, the framework has more integrity, and the cultural and economic layers should benefit from being suitable to the site.

The idea of site-suitability can be traced from the “Ecological Method” of Ian McHarg (1969), which argues for the importance of the landscape architect and regional planner to know the physical aspects of the region in question: topography, soil composition, hydrography, aquifers, vegetation, climate. Historical human activities mostly happened according to these characteristics, as stated in Patrick Geddes’ primordial Valley Section, and so should human occupation of the territory happen nowadays. More recently, the model of Landscape Urbanism has been advocating for landscape and urban planning to consider the physical landscape and

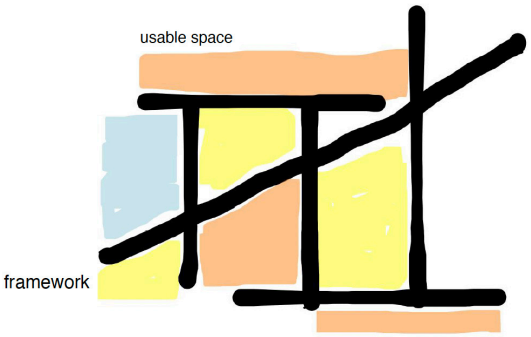


Fig. 14

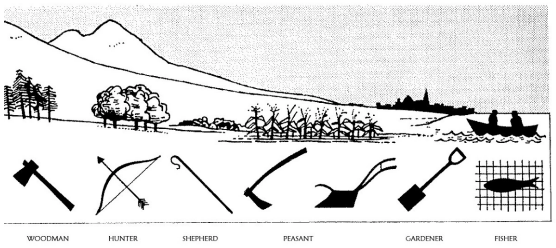


Fig. 15

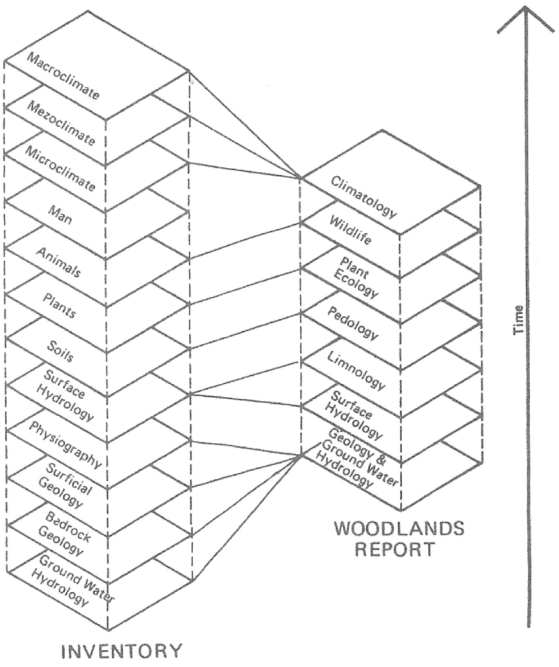
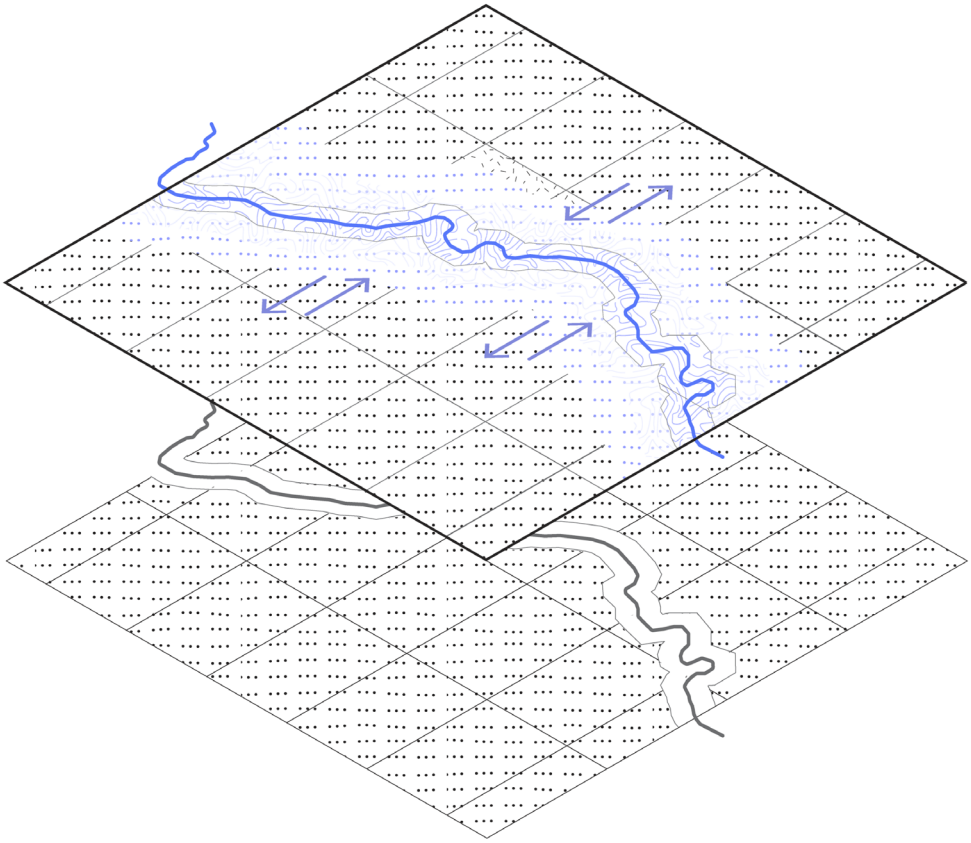


Fig. 16

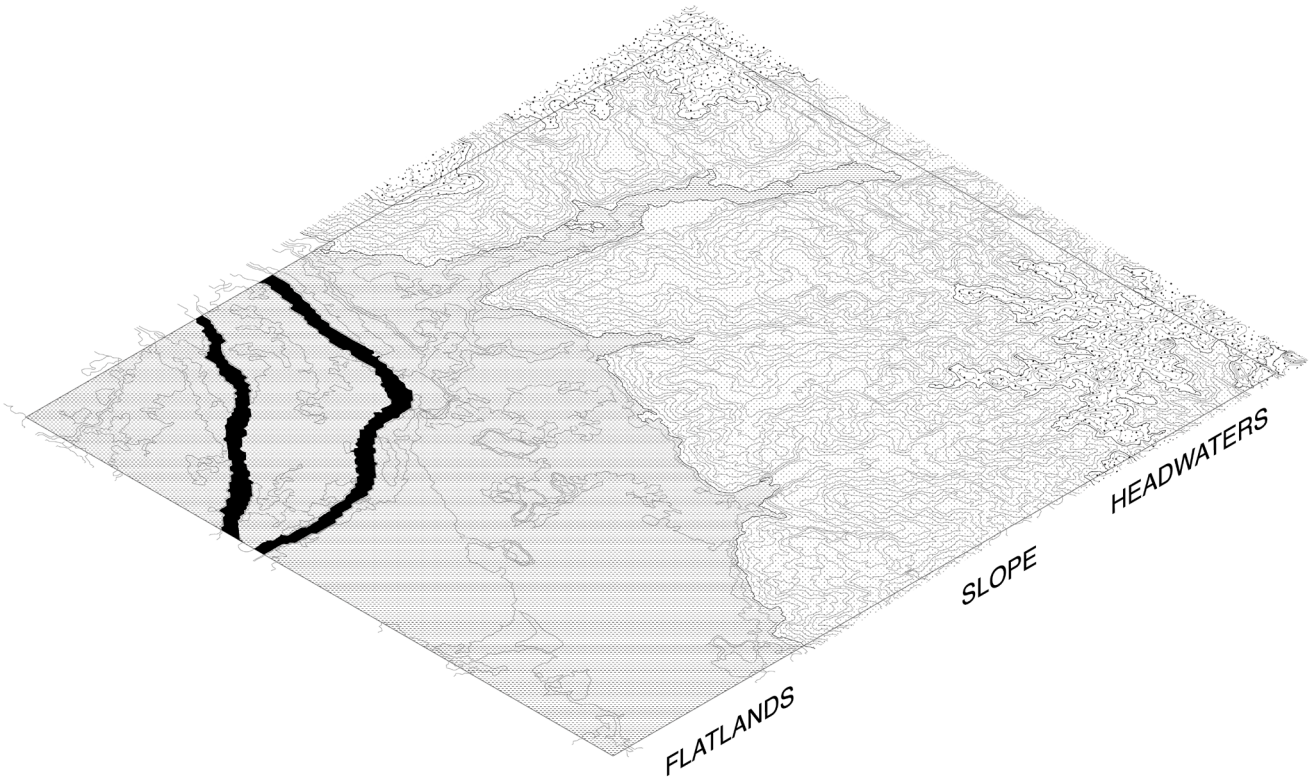
its associated ecological processes as the starting point because it leads to the most advantageous spatial and relational arrangements of places and functions (Nijhuis, 2022).



04. How can Principles Become Spatial?

04.01 Introduction

This chapter gathers the knowledge accumulated in the previous sections and aims to apply it to the landscape. First, it presents a set of operative spatial strategies that can be considered for a regional plan based on references and examples of work, executed or not. These strategies express the ideals present in the principles chapter (chapter 03), but not in a one-to-one correspondence way, more as an overlapping matrix of different strategies being activated by a single principle. After that, a regional plan and three zoom-ins aim at depicting this exploration at varied scales.



04.02 Principles made operative

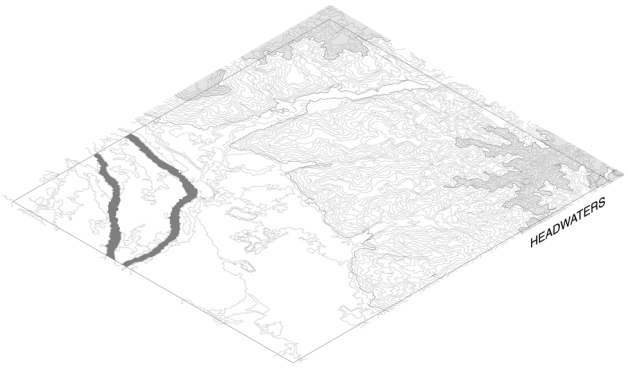
A search for principles means working with a certain abstraction of the landscape: identifying, among all the infinite specificities in each small zoom-in, what are the typical aspects or features that regional planning can work with. Considering the framing of this research, which is water retention capacity, a topography-oriented approach was chosen, so the abstraction is directly linked to rainwater runoff. In this sense, the three basic topographic elements of the water cycle in the region are: the headwaters, the slopes, and the flatlands. These components are everywhere across the Upper Paraná River basin. Simulations made using AutoCAD Civil 3D show how rainwater interacts with each of them.

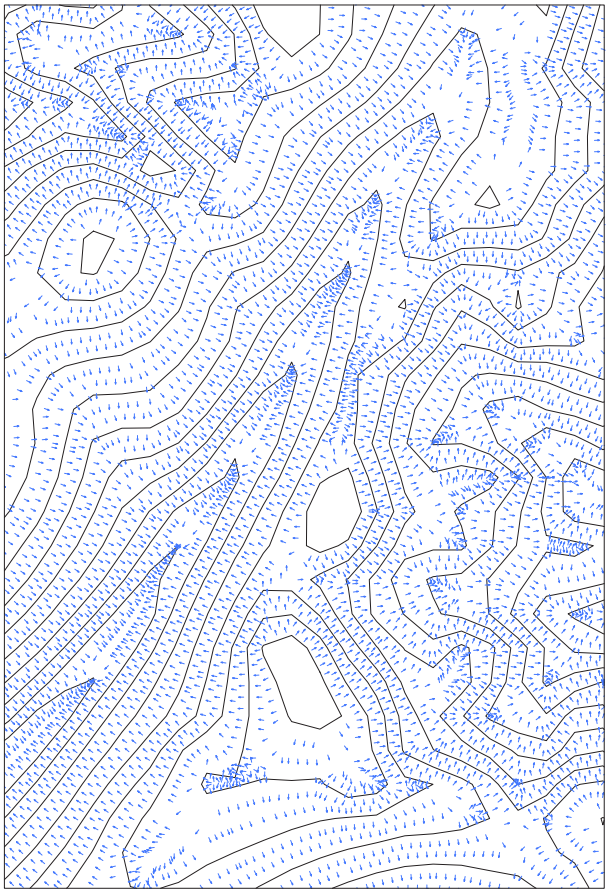
For the headwaters, the main guideline is to protect them from pesticides and urban pollution since they are points where the Guarani Aquifer is very exposed. Protection consists of regenerating the vegetation around it, which can be initiated with pioneering species that tolerate wet conditions, such as Croton floribundus, Cecropia pachysfachya, and Ficus guaranítica. They can start a process of natural succession to revegetate the area, which can even dry for a certain period because of the development of the root system. This will also prevent the spring from silting up, a common cause of disappearing streams.

For the slopes, the primary strategy is to work with contour planting, whose implementation will be further described in the following zoom-in section. Contour planting is expected to stimulate water infiltration into the Guarani Aquifer and retain sediments coming from monoculture fields. Furthermore, it can be used as a tool to address other pressing issues, such as habitat fragmentation, by connecting remaining patches and increasing the connectivity in the landscape. It can connect existing riparian corridors, since the current law generates “isolated branches” of protection. Infrastructural lines, which are currently barriers for flora and fauna, can be surrounded by planting to become corridors.

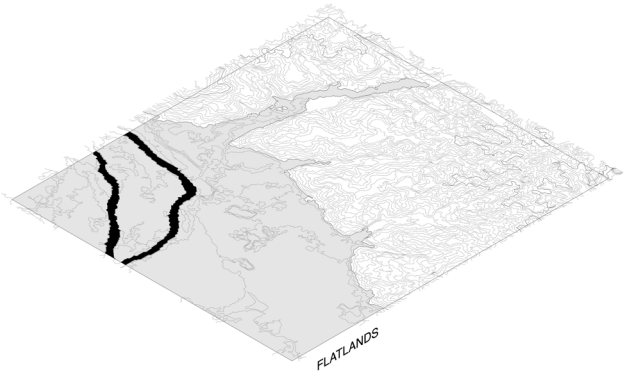
The number of contours can vary according to economic cycles and specific local needs, as an adaptive framework. For example, in areas where the aquifer is more exposed, there should be more contour planting, as a way to neutralise potential harms and make use of the opportunity to recharge the aquifer: these areas are aquifer recharging zones and should be specially protected and planned. The creation of retention lakes at the confluences of the streams increases the water residence time, stimulating deep infiltration into the aquifer.

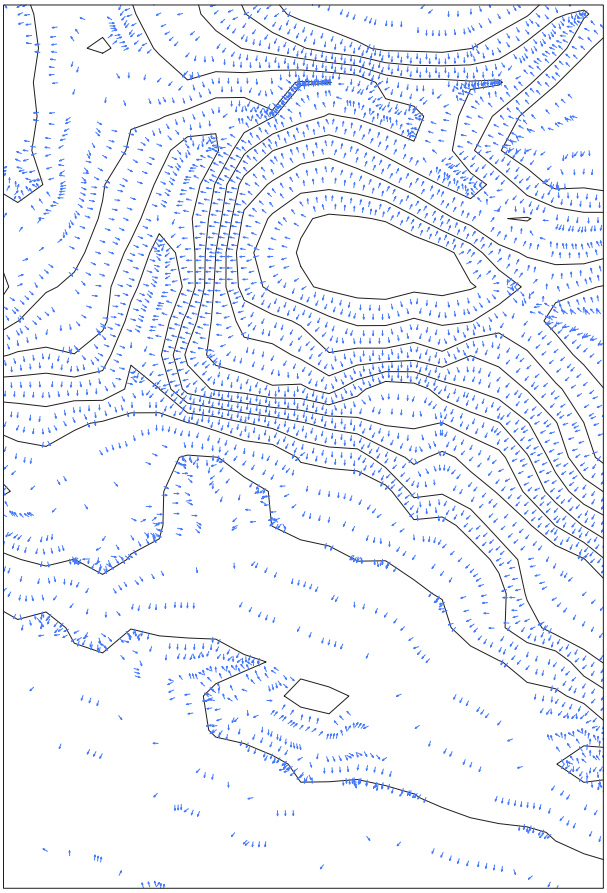
HEADWATERS



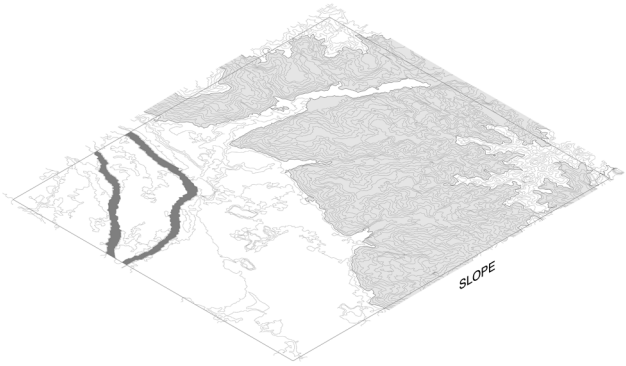


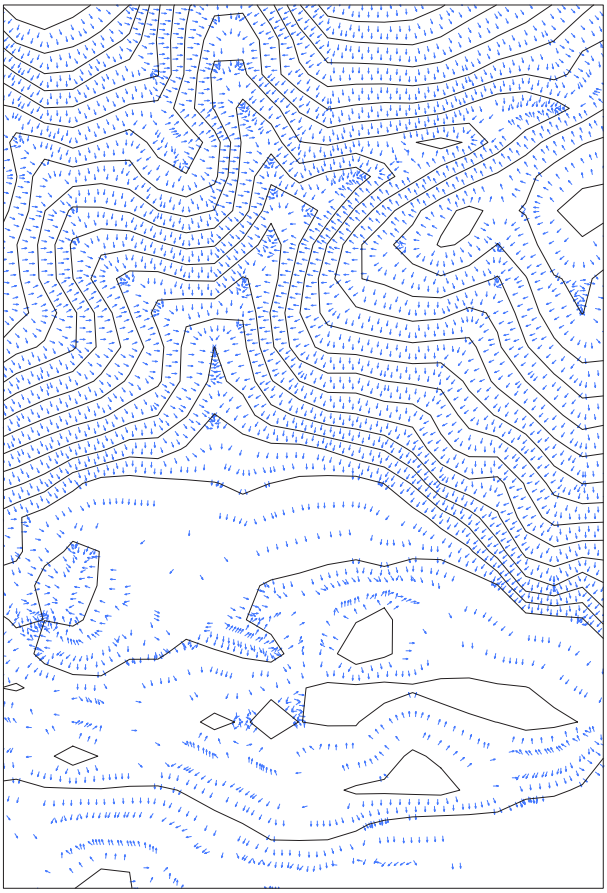
FLATLANDS

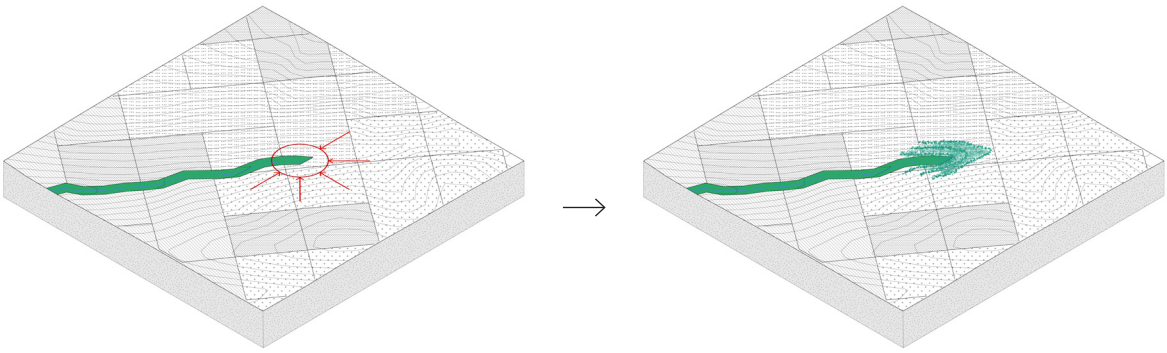




SLOPES

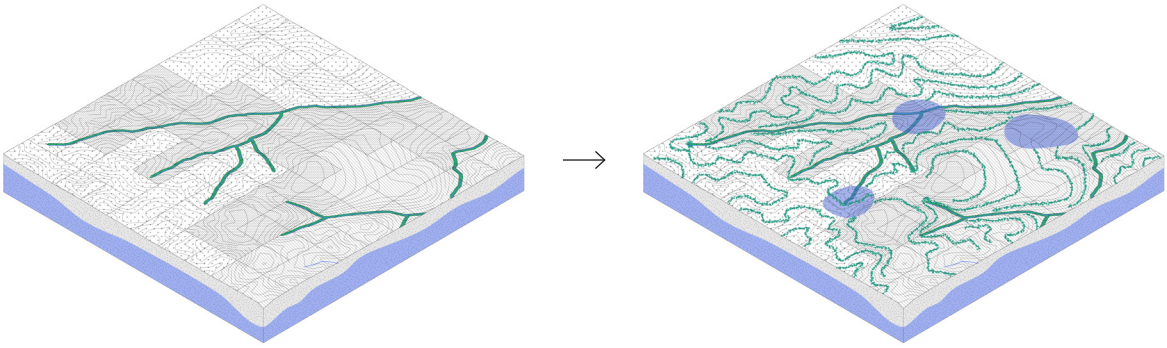






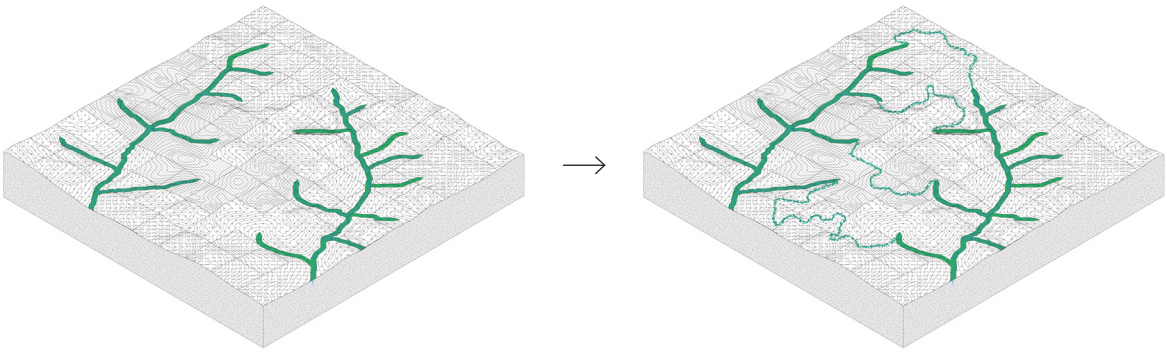
Water springs are degraded and unprotected, causing them to silt up and affects the quality of groundwater.

To unsilt them, and protect them with layers of vegetation and barriers for erosion control.



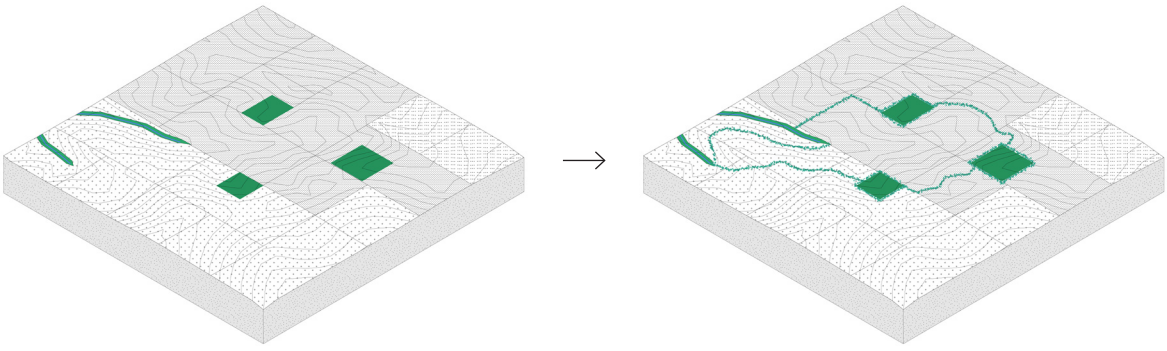
There are areas where the aquifer is extremely exposed under thin layers of porous soil.

Create aquifer recharge and protection areas, with extra planting and infiltration lakes.



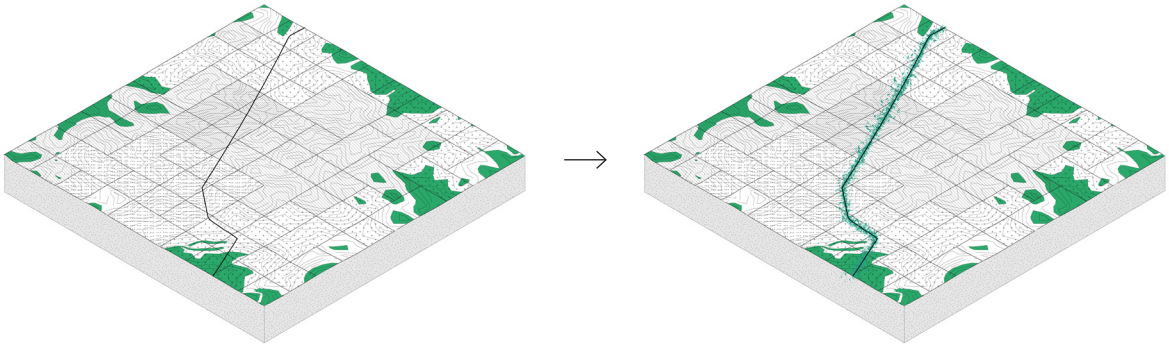
The current legislation generates isolated green “branches” along streams.

Enhance landscape dynamism by connecting the branches.



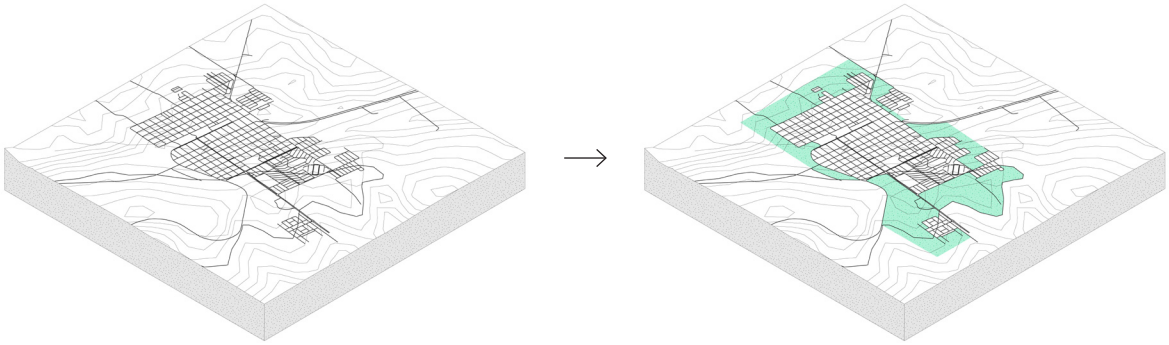
Agricultural industries create intense habitat fragmentation.

Contour planting should be planned as to increase landscape connectivity.



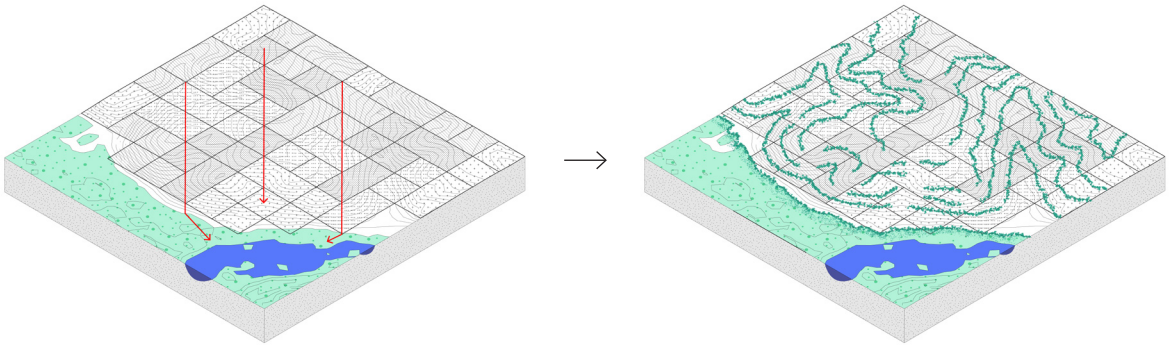
Infrastructural lines are cutting the territory, acting as barriers for plants and animals.

Characterize infrastructural lines as corridors for circulation.



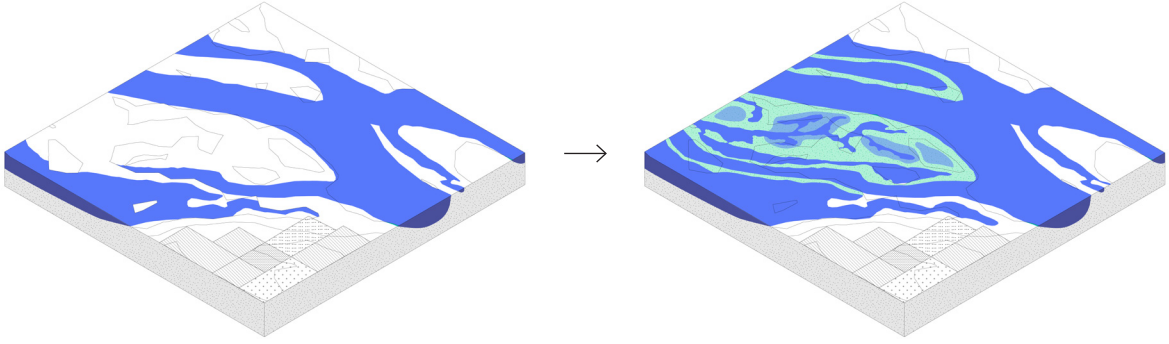
Cities are very sprawled and not dense at all.

Define urban sprawl control belts with different land uses.



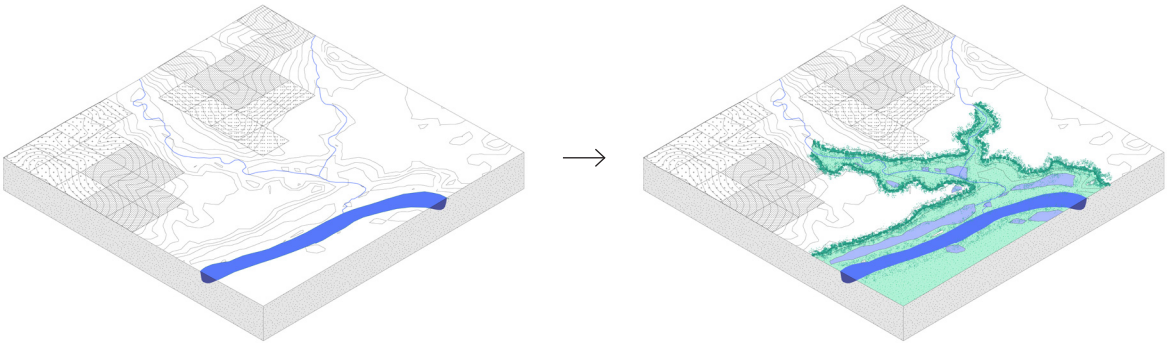
There is little water infiltration and too much soil erosion (15 ton/ha/year) in monoculture fields.

Contour planting associated with ditches, in intervals adapted to different land uses and situations.



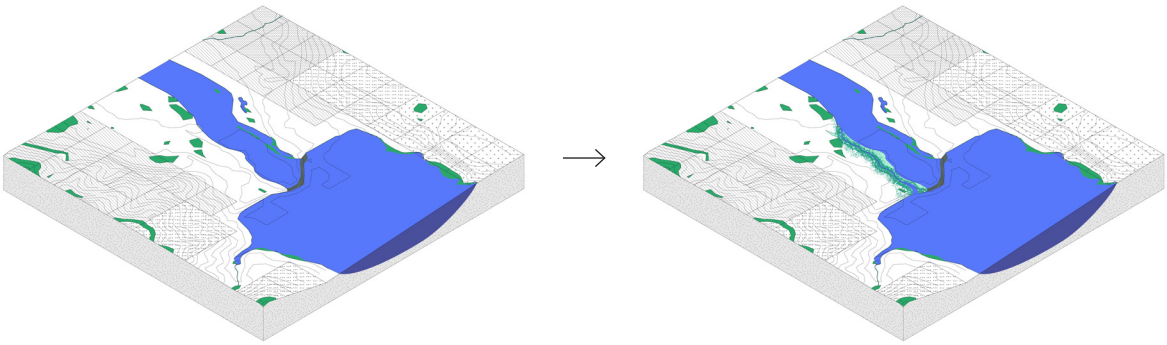
Riverine islands got degraded, because of deforestation or dam construction.

Allow water to enter the islands, recreating previous marshlands.



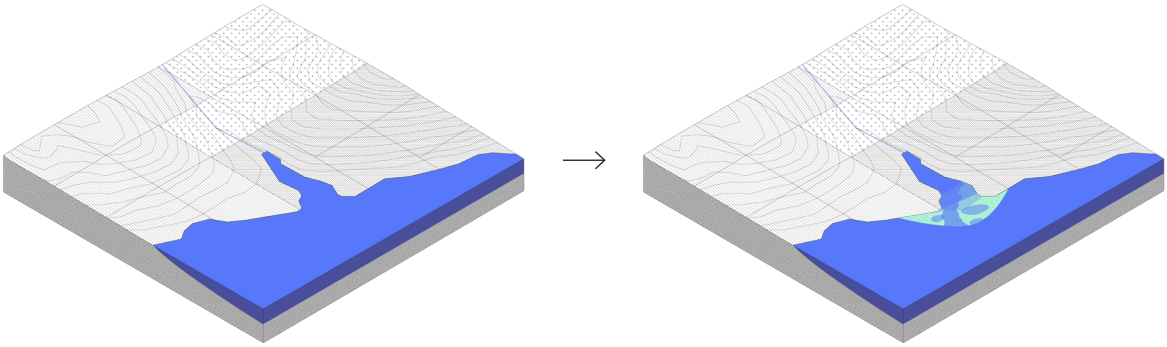
Marshlands dried due to the construction of dams.

Use transversal flows to regenerate them, creating varied lakes and new gradients for protection.



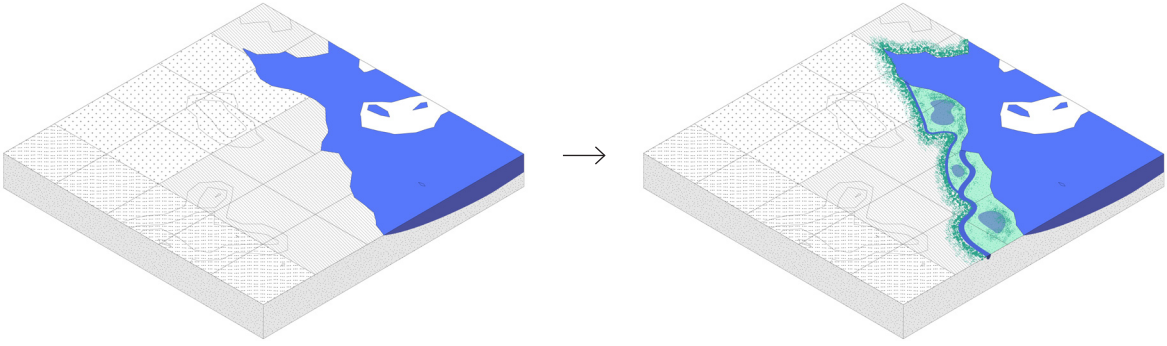
Dams trap sediments and nutrients that are necessary for ecosystems downstream.

A bypass could partially restore nutrient and sediment input.



Reservoir are prone to water eutrophication due to sediments coming from streams.

Work with sedimentation to create filtering marshes.



Plantations reach the Paraná River, leaving no buffers or filters

Creating bypasses help reinforcing a framework

Finally, there is a pressing issue of a lack of gradients and buffers in the slopes. Remaining patches are declining, which calls for implementing more gradients to counterbalance the edge effect. Cities can currently sprawl without any physical control, because space is seemingly infinite.

For the flatlands, the construction of the dams is the root of many problems. The dams cause marshlands to dry, trap sediments and nutrients, and cut seasonal water level variations and related ecological processes. Dry marshlands can be regenerated by creating bypasses in the Paraná River and using transversal flows, rainwater coming down from the slopes, forming retention lakes of varied depths. A bypass around the dams would decrease its hydroelectric production but would restore the essential sediment and nutrient flows for the system to work. The lack of seasonal floods combined with human-induced deforestation caused many riverine islands to degrade, and allowing water to enter them can help recover ecological value. On the other side of the dam, the reservoirs experience high levels of water eutrophication due to the excessive sediments coming from the streams, which could be addressed by working with sediment-trapping plants to create filtering marshes. An example of a plant is the Southern Cattail (Typha domingensis), already abundant in the region.

To conclude, the flatlands also suffer from occupation by human-led agricultural industries, such as cattle ranching and sugar cane plantations. They might reach and occupy the banks of the Paraná River, leaving little or no riparian vegetation for protection. Possible solutions could be implementing an offset buffer of riparian vegetation, and creating side channels, retention lakes and marshlands, to add diversity and ecological value to these degraded lands.

04.03 Regional planning

A group of watersheds were selected as the case study for applying theoretical and operative principles. The selection comprises sixteen watersheds, geographically defined according to the hierarchy defined by Linke et al. (2019) and corresponding to level 4 of their classification. The study area is located on the Paraná River, downstream of the Jupiá reservoir. It was chosen for two main reasons. Firstly, it was the location the author could visit because of accessibility matters, so the body of knowledge about this region is much more abundant than about the rest of the UPRB. Secondly, it is a sample of watersheds that is very representative of the general conditions of the UPRB. In terms of topography, soil composition, with the critical Guarani aquifer sitting underneath them; in terms of infrastructure, with the Engenheiro Souza Dias hydroelectric dam, the Jupiá reservoir, and the railway connecting the region to the port of Santos, where commodities are exported; in terms of ecosystems, consisting of a transition zone between the Atlantic Forest and the Cerrado biomes; in demographic terms, being Três Lagoas the most extensive urban agglomeration along the Paraná River; and in terms of land use, because of the representative combination of grazing fields for cattle, sugar cane production, and the eucalyptus industry, accompanied by a highly relevant cellulose processing plant. The selection of the sixteen sub-basins is justified by the goal of forming a very representative body of situations in which the principles can be tested.

As stated by the theoretical principles, the main goal is to create an adaptive framework capable of supporting all living beings in the landscape to withstand disturbance events. Therefore, the first step in the regional design was to define the framework for the Paraná River, the flatlands.
The framework for the flatlands is based on the vision that the Paraná River was originally an ecological corridor crossing a significant stretch of South America, full of marshlands with dynamic degrees of connectivity and, therefore, different biotopes, forming a picture of high biodiversity value. The goal is to restore such dynamism and heterogeneity as much as possible. A reading of the current situation of the flatlands in the region shows that in significant stretches, there are grazing fields or sugar cane plantations reaching the margins of the river, devoiding them of ecological values and water retention capacity. There are also many areas of dried marshlands, probably as a result of the construction of the hydroelectric dam. The primary design operations consist of recreating vegetated buffers between anthropocentric land uses and the river, also connecting remaining patches of native vegetation using Landscape Ecology principles and regenerating the marshlands, assuming that these areas have a soil composition that is favourable for such. Their regeneration would happen by creating river

detours and bypasses, accumulating in specific points as new marshlands and lakes of varied depths and water input. Furthermore, steeper areas should be prioritised for ecosystem regeneration, and infrastructural lines (railways, roads) can be used as ecological corridors to increase the connectivity of the landscape (Dramstad et al., 1996).

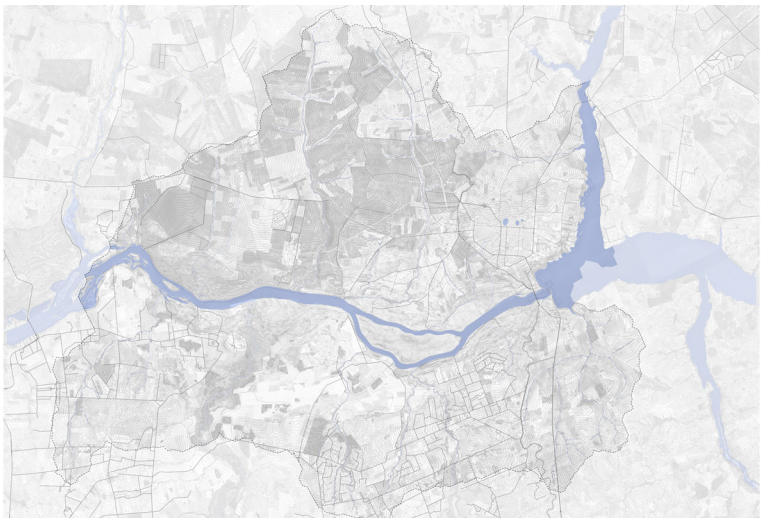
The framework for the slopes focuses on slowing rainwater runoff, preventing soil erosion, facilitating aquifer recharge, and enhancing connectivity from a Landscape Ecology perspective. It accomplishes so mainly through contour planting, which means that corridors of vegetation combined with land forming (such as ditches) would be implemented following the topography. A simulation made in AutoCAD Civil 3D shows how rainwater flows in this typology of relief, which elucidated the fact that most of the runoff happens at the lateral parts of the hills, towards the tributaries, which should therefore have more contour planting implemented. Areas that are steeper and closer to the Paraná River framework should also be prioritised. Finally, land use is another criterion for the definition of contour planting because the different industries in this landscape have different water retention features and dynamics. According to the analysis presented in Chapter 2, grazing fields are the most problematic type of land use because of their lack of vegetal strata and soil exposure due to overgrazing. Also, there is no circulation of heavy machinery, which is an advantage, considering the partitioning that contour planting entails. The tracing of these corridors follows the guideline of connecting remaining patches of native vegetation and sewing together the isolated stretches of riparian vegetation.

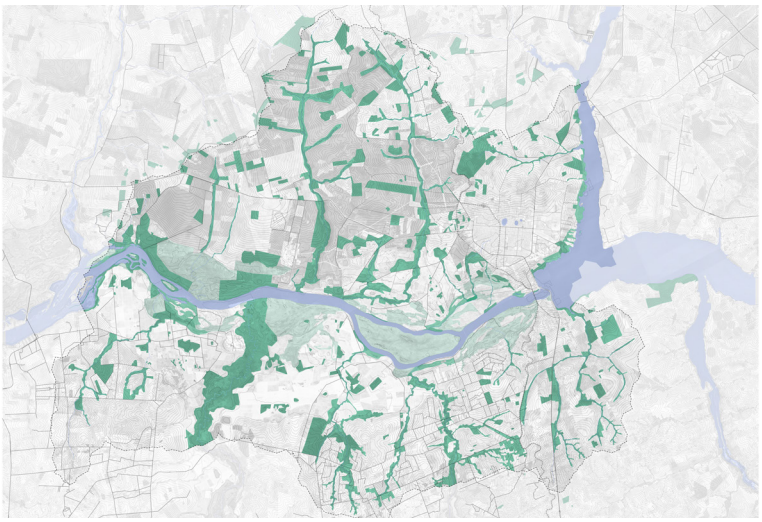
A special demarcation of the slopes is the aquifer recharge area. In the study delimitation, there are no areas where the Guarani Aquifer is extensively exposed, except for the punctual moments of permanent water springs. However, there is a significant extension where the layer covering the aquifer is not very deep, between 10 and 500 metres and consisting of porous sandstone formations. If on the one hand, the fact that the aquifer is so exposed means that it is very vulnerable to contamination, on the other, it has a great potential of being a recharging area that helps the Guarani Aquifer get back to stability. A regional design for this region should prioritise implementing more contour planting in this aquifer recharge zone, as well as working with land forming to create retention areas, making use of the natural topography. This way, the water retained can slowly infiltrate the aquifer, steering the system back to equilibrium.

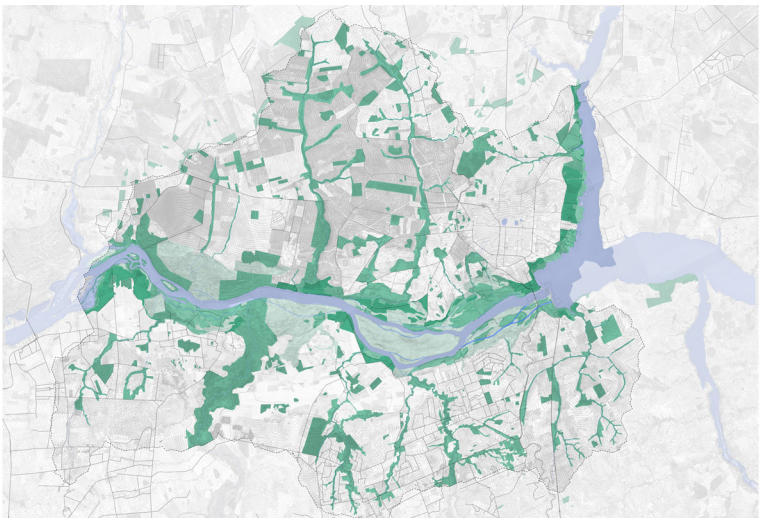
As for the headwaters, they are generally understood as points where the aquifer is exposed and should therefore be protected. There are perennial, semi-perennial and intermittent rivers in the region, but recent

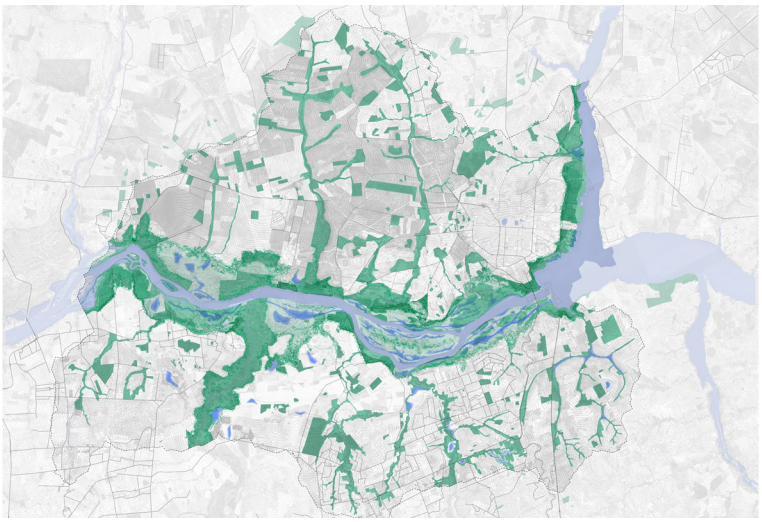
droughts and drops in the level of the Guarani Aquifer make it complicated to determine which river corresponds to each type and therefore set different criteria for their protection. In general, buffer zones between the springs and agricultural uses should be created to filter pollutants and sediments coming from the hills, preventing aquifer contamination and the silting up of the spring.

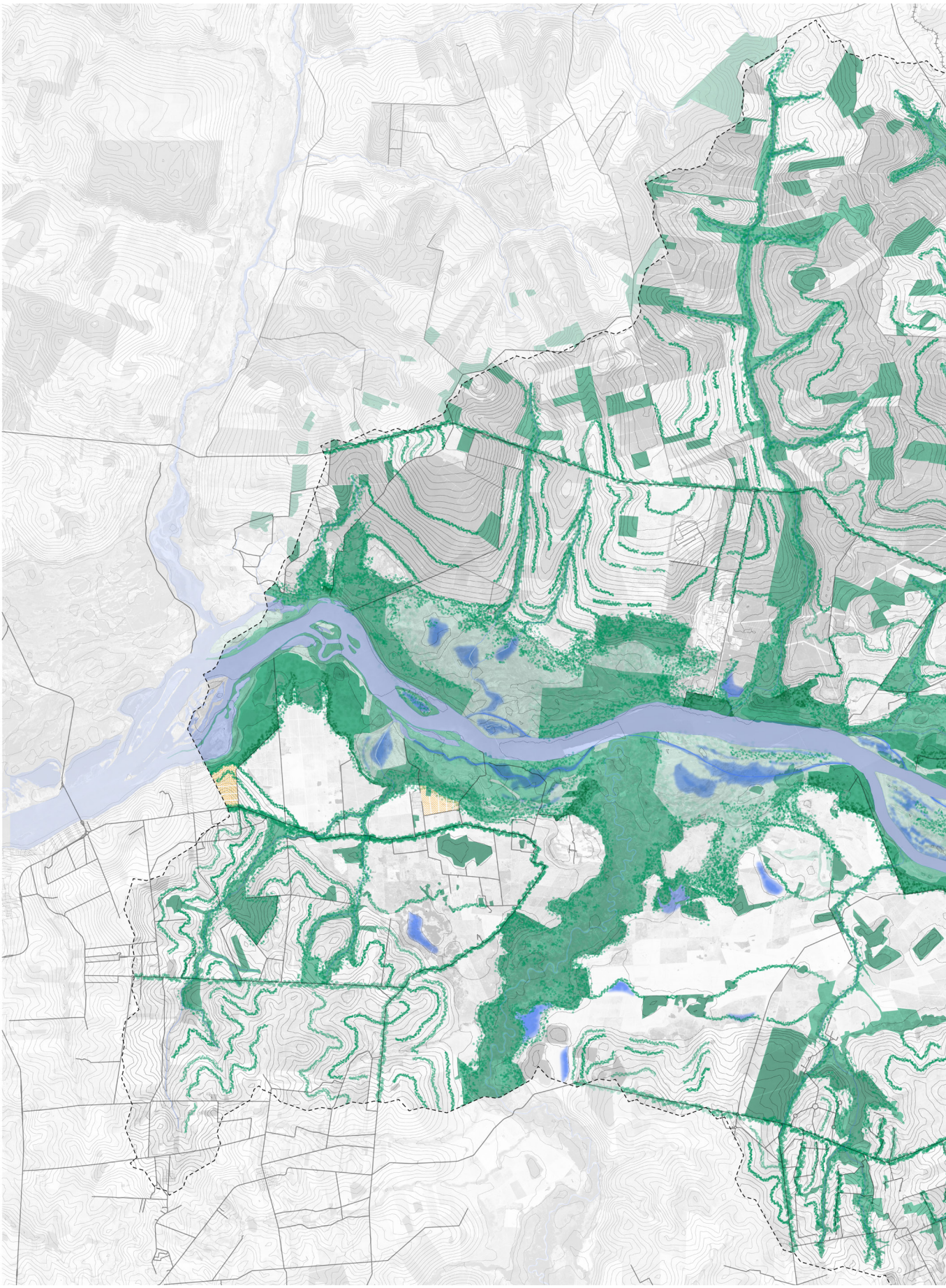
Finally, what is left of native vegetation in the region is pressured by the sharpness of the limits between ecological frameworks and user spaces. The re-introduction of gradients is essential to strengthen and protect the frameworks of the flatlands, the slopes and the headwaters from the pressures of the edge effect, the use of pesticides, and other human-led activities. Gradients can consist of gradual assemblages of native species varying in their level of maturity; agricultural practices more tuned to existing ecological processes such as permaculture and agroforestry; and recreational uses can be an essential occasion to foster contact and familiarity with the landscape. Permaculture belts can be placed strategically to hold accelerated urban sprawl around human agglomerations, generating job opportunities at shorter distances.

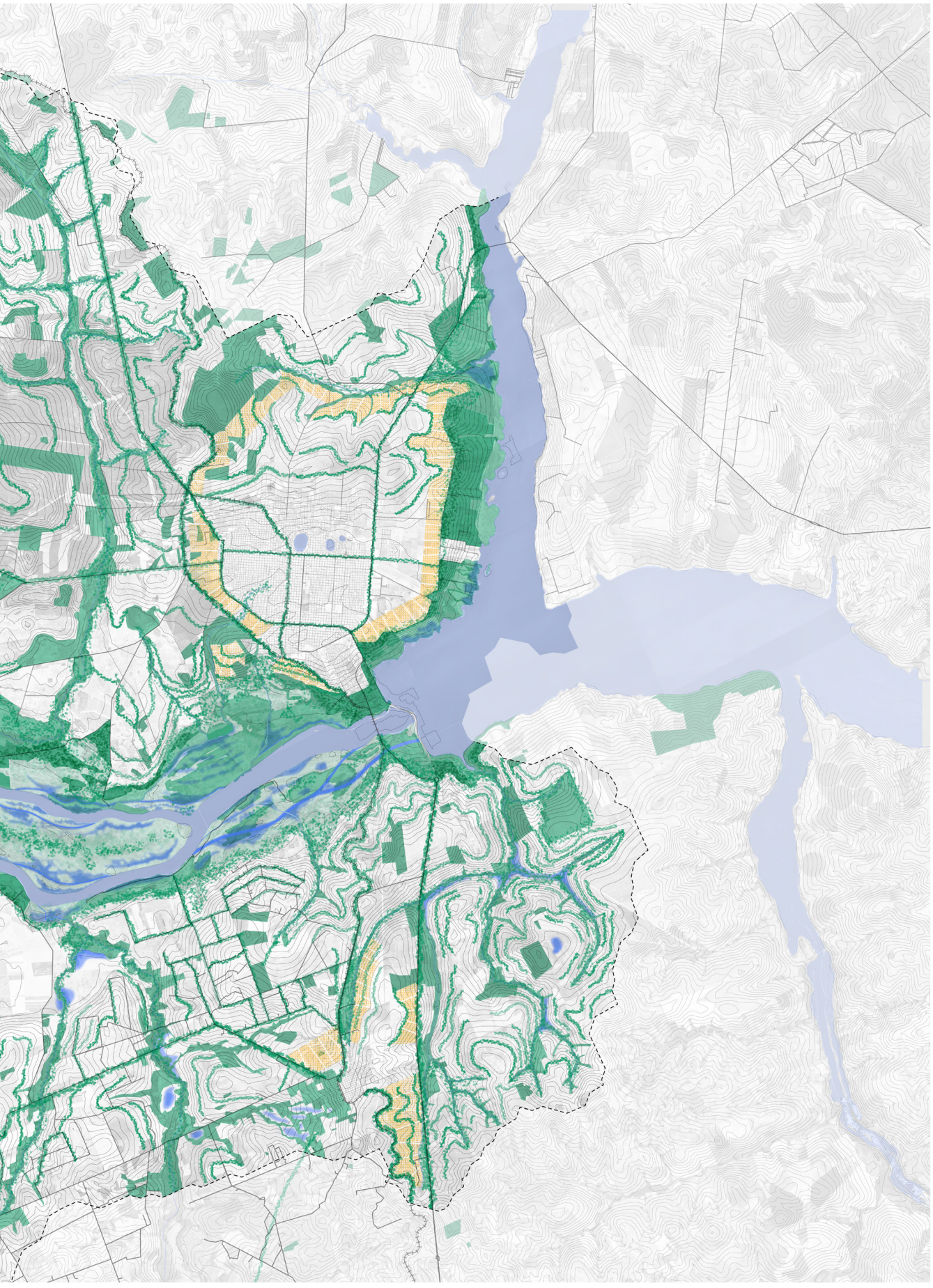












04.04 Zoom-in A: Headwaters, the public square (-20.793734, -51.705533)

The first design exploration is located at the Central Market Square of the city of Três Lagoas, which currently is a 240 x 50 metres impervious concrete slab within the grid-like urban tissue. The location, used as a parking lot, was chosen because it is the headwaters of the Onça stream, whose spring is buried underneath the slab mentioned above. The Onça stream flows in an underground channel for a diagonal of 6 urban blocks, or roughly one kilometre, before rising aboveground at a public park. The first information about the buried spring came from a local inhabitant whose automotive workshop is situated nearby the park: as a kid, he would cross the gates at the entrance of the concrete channel, walk underground along the buried river, and rise again through the gates at the Central Market Square.

A certain urgent need for redesign comes from the fact that the buried spring currently receives all the pollution from its urban surroundings since all rainwater is drained towards it, and there is no greenery left to filter all the large and diffuse pollutants coming from the city. Every spring is a fragile area where the aquifer is very exposed, so protection is vital. Furthermore, the fact that the Central Market is the social heart of Três Lagoas calls for the cultural potential of landscape design there. Landscape architecture can create narratives that help people understand their context and the biome they are part of. Every two days, a big hectic evening market happens inside the Central Market building, combining groceries stalls with locally-planted products, food tents with local dishes, and not rarely live music performed by local musicians. Therefore, this square is a place of very high visibility, which is very positive for the educational potential of landscape architecture.

In other words, the main goals of the headwaters design are to protect the spring and, consequently, the aquifer, and to promote an ecology-oriented identity affirmation. The need for an identity affirmation lies in the Upper Paraná River Basin being a plantation landscape, with all its features discussed earlier in this report, since many decades ago (at least the 1970s). This means that most inhabitants are unlikely to have experienced that landscape before widespread deforestation and the engineering of the Paraná River. Despite the many references to local animals scattered through the city, present in trash bins and information panels, the native biomes of the Atlantic Forest and the Cerrado have been pushed further away from the city. In conclusion, the design for the headwaters is strongly related to the cultural and identitarian aspects of landscape design.

As a last addition, the ontological aspect of design stresses its

relevance and potential in times of deep environmental unrest. Ontology stands for a society's idea of what the world is, who they are, and how such narratives shape their attitudes and behaviour. The ontological aspect of design stands for the belief that design can itself create new ontologies and shape ways of being because it is the act that sets how tools, objects, buildings, and systems work in a broad sense. In short, as Escobar (2018) put it, "We design our world, and our world designs us back". Applying this statement to landscape design would probably result in the idea posited by Natasha Myers (2017): "Turning tropically to one another, plants and people are both in the making in sites like gardens". Gardens, in a broad sense, are, on the one hand, spaces where the current human-plant relationships are depicted, be they of extraction (plantations), rigour (Versailles) or wonder (Hortus botanicus). On the other hand, gardens can also propagate interbeing relations. They are spaces able to foster a dialectical process of human-plant relationship-making, which should be pivotal in times of ecological crisis.

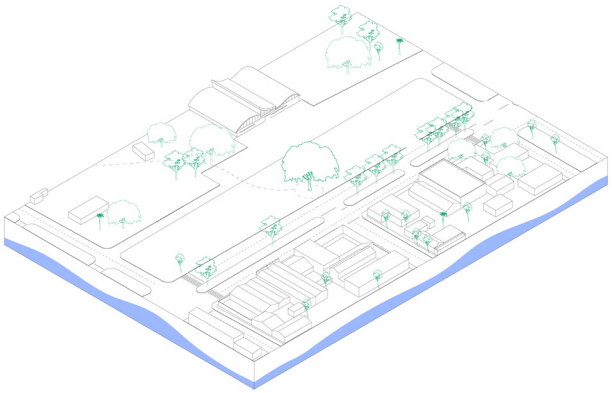
The first premise of this design is that the water spring is protected by an offset of 60 metres, considered by many authorities to be a reasonable minimal distance. That means that occupation within this offset should not be intensive, the soil should be as permeable as possible, and there should be many vegetal filters to stop pollution from reaching the aquifer.

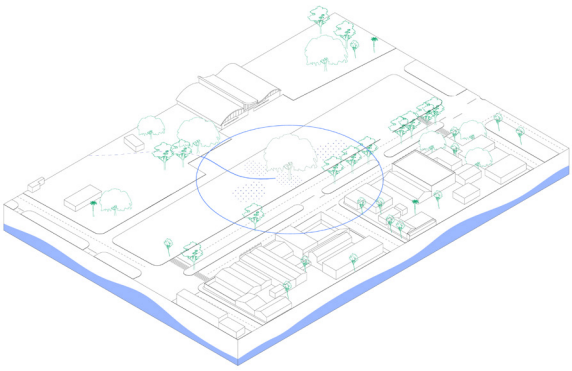
The second premise, which is based on the ontological aspect of design and the educational potential of landscape architecture, is that the square is an illustration of processes that happen in the landscape, such as slow rainwater runoff due to accumulation in ponds, or seed dispersal by birds coming to look for food in native fruit trees. Similarly, maintenance should keep fallen leaves and fruit on the ground to reintroduce the idea of natural rotting and death, so foreign to plantation landscapes. Natural succession should be allowed in the planting areas, but open areas should be kept open for leisure.

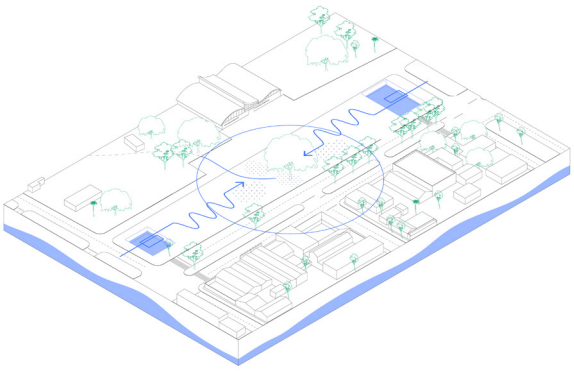
The third premise is that the square should portray relations of human ecological care, as opposed to creating a narrative where plants are there only as providers of "ecosystem services" for humans (e.g. in the form of shadow, fruit, beauty), in a single-way sort of relationship. Ecological care tackles the topic of community participation, which is never a given, and it should be safer to design spaces where people can participate if they want but whose quality as a place exists regardless of that. The square could offer compost spaces where the street market's leftovers could be processed. Other acts of human ecological care can be staged through design, as in human-made features offering spaces for birds to nest and drink water and explicitly showing human acts of garden maintenance, for example.

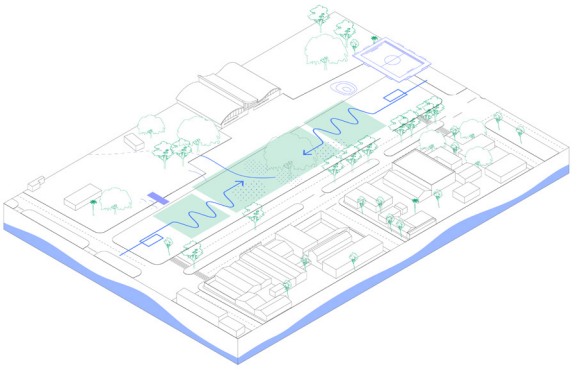
A grid of 5 x 5 metres is projected on the square and overlaid with the 60-metre protection offset of the spring. Two perpendicular armatures organise the remaining space. The first is connected to the commercial aspect of the square: it creates a boulevard under the shadow of a grid of trees, a homogeneous canopy that enables the market to happen outside even during the hottest months of the year. While the boulevard exists along the façade of the existing Central Market building, four perpendicular axes connect it to the main avenue (Avenida Rosário Congro), located at the other side of the square. Two of these axes are imagined to be more fast-paced and functional, paved with tiles, whereas the other two, located within the edge of the 60-metre offset, are slow-paced, paved with gravel, and more contemplative of the presence of the water spring. The axes are spatially reinforced by a pergola structure, which adapts to different situations by offering shadow (the function of an ombrière) or protection from the rain. These four axes define five different moments of the square, which are connected to the idea of illustrating water processes of the landscape: the two parts at the edges are designed as underground retention tanks, topped with a small soccer field and a sub-square with playful water sprinklers; when the tanks are full, water flows into the two subsequent parts, which are open-air retention ponds; once they are complete, water finally reaches the central moment, the spring, in a marshy terrain of bubbling water and moving grounds.

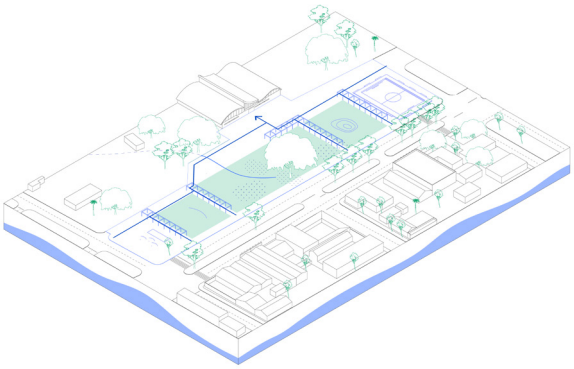
The second spatial armature crosses the four axes perpendicularly, consisting of a parcours aligned to the longest direction of the square, a promenade through all of its different moments that unite the whole, binding them together. This armature is in gravel because it is not expected to be functional or fast-paced but for contemplative walks. For the same purposes, it is not linear but meandering and full of detours.

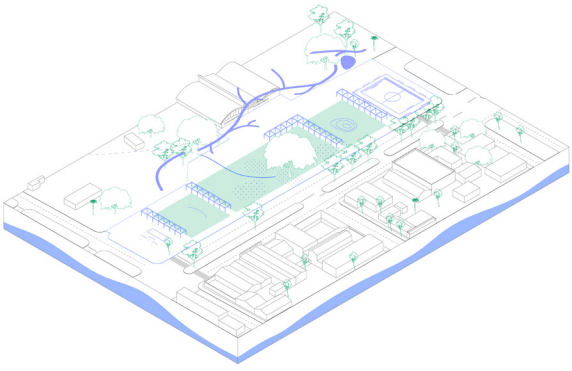


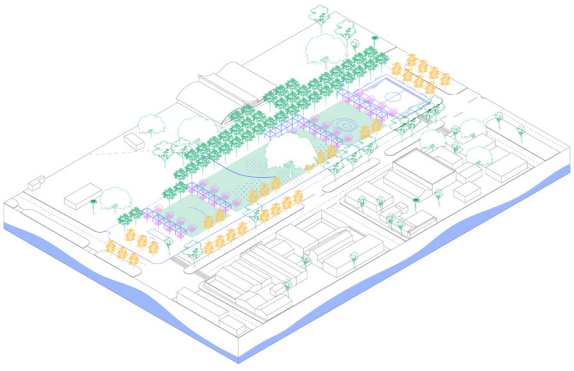


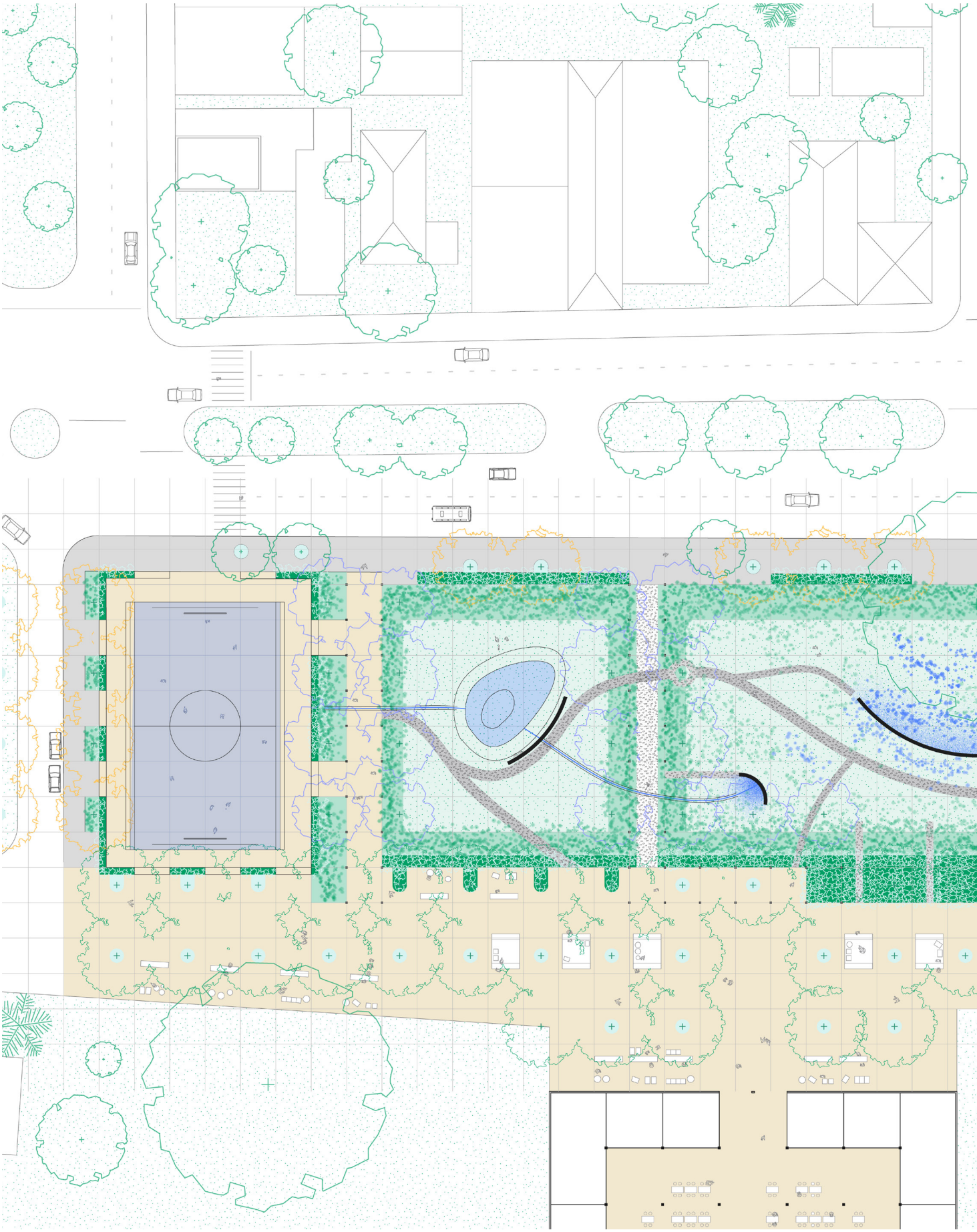


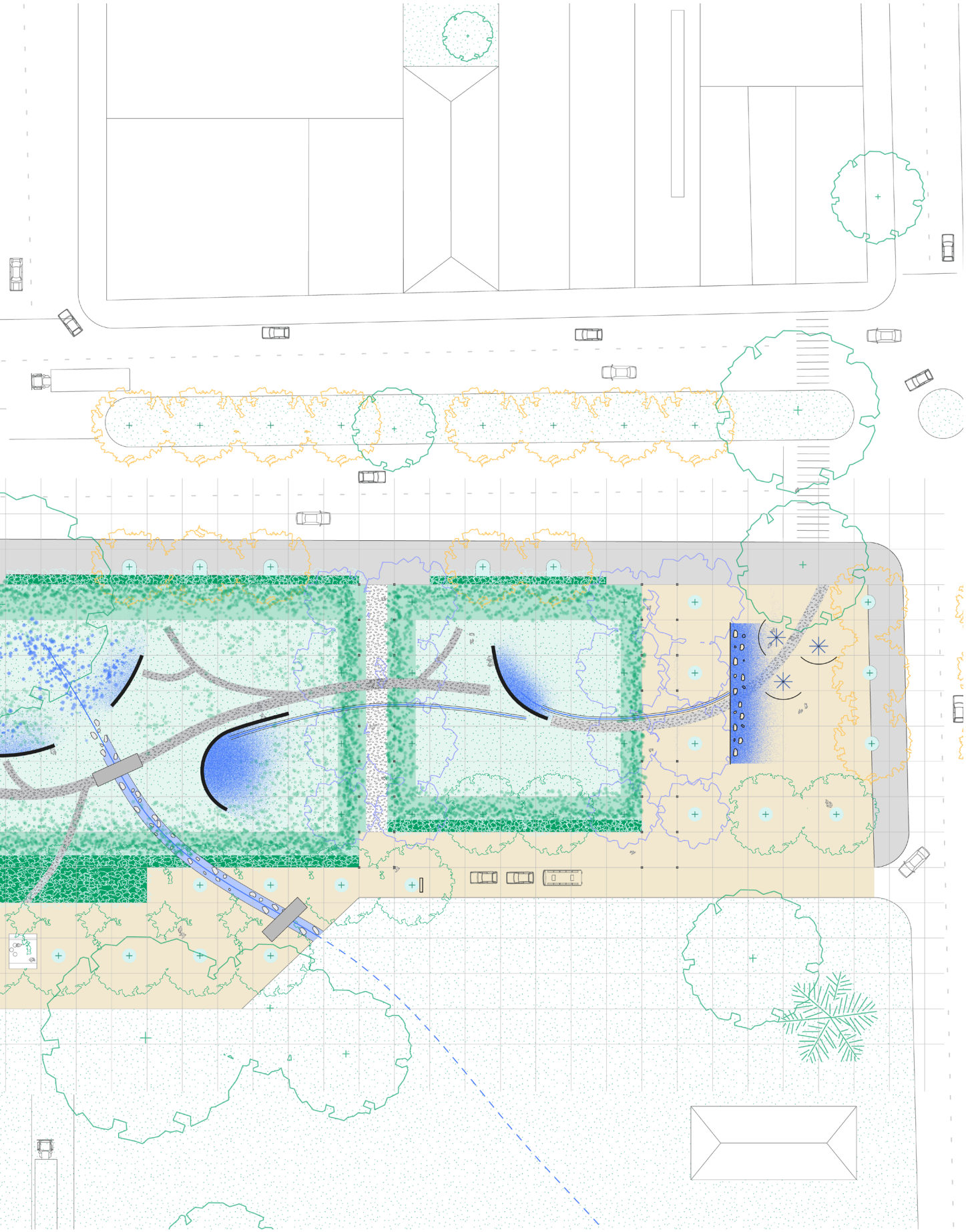


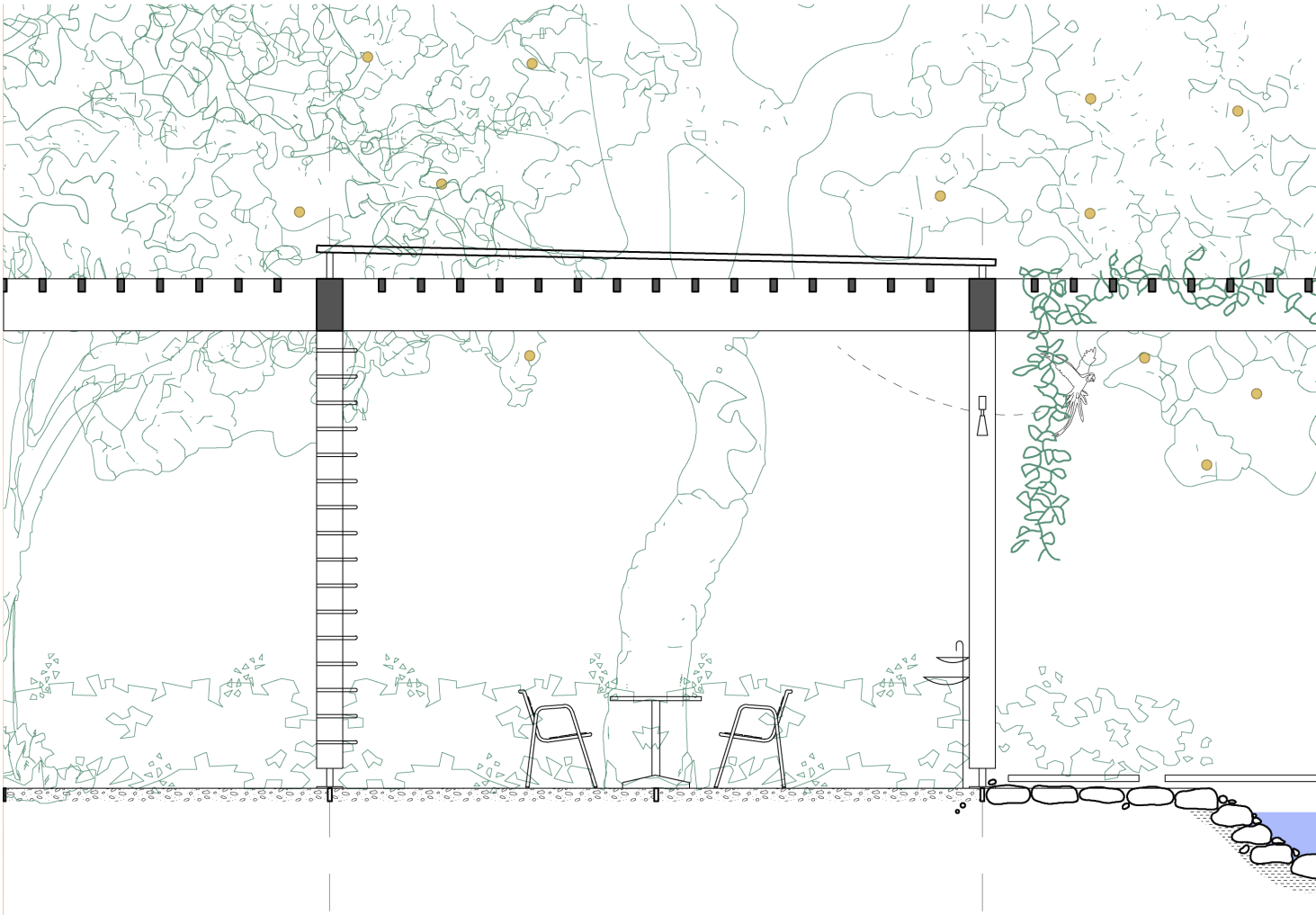


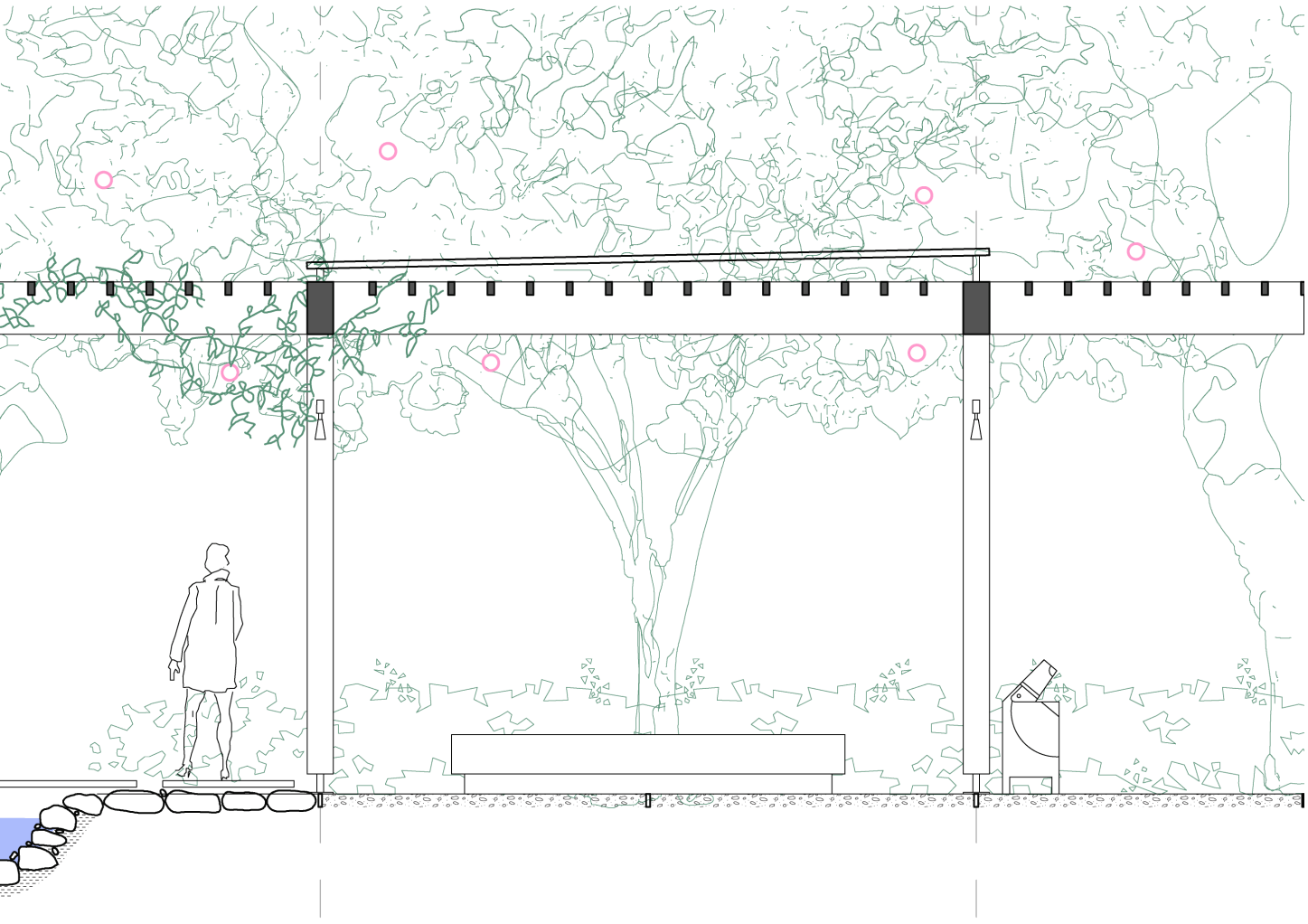


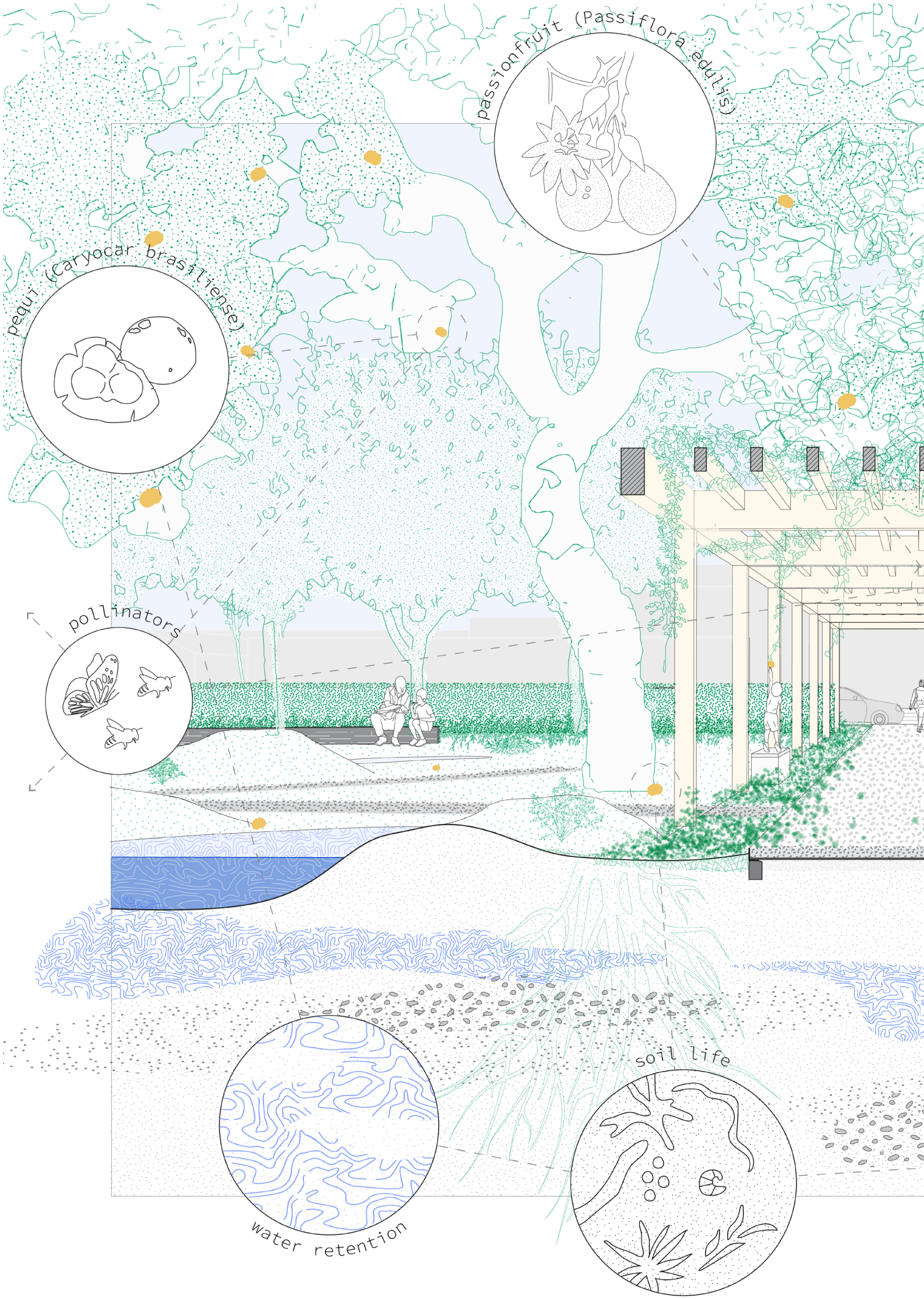


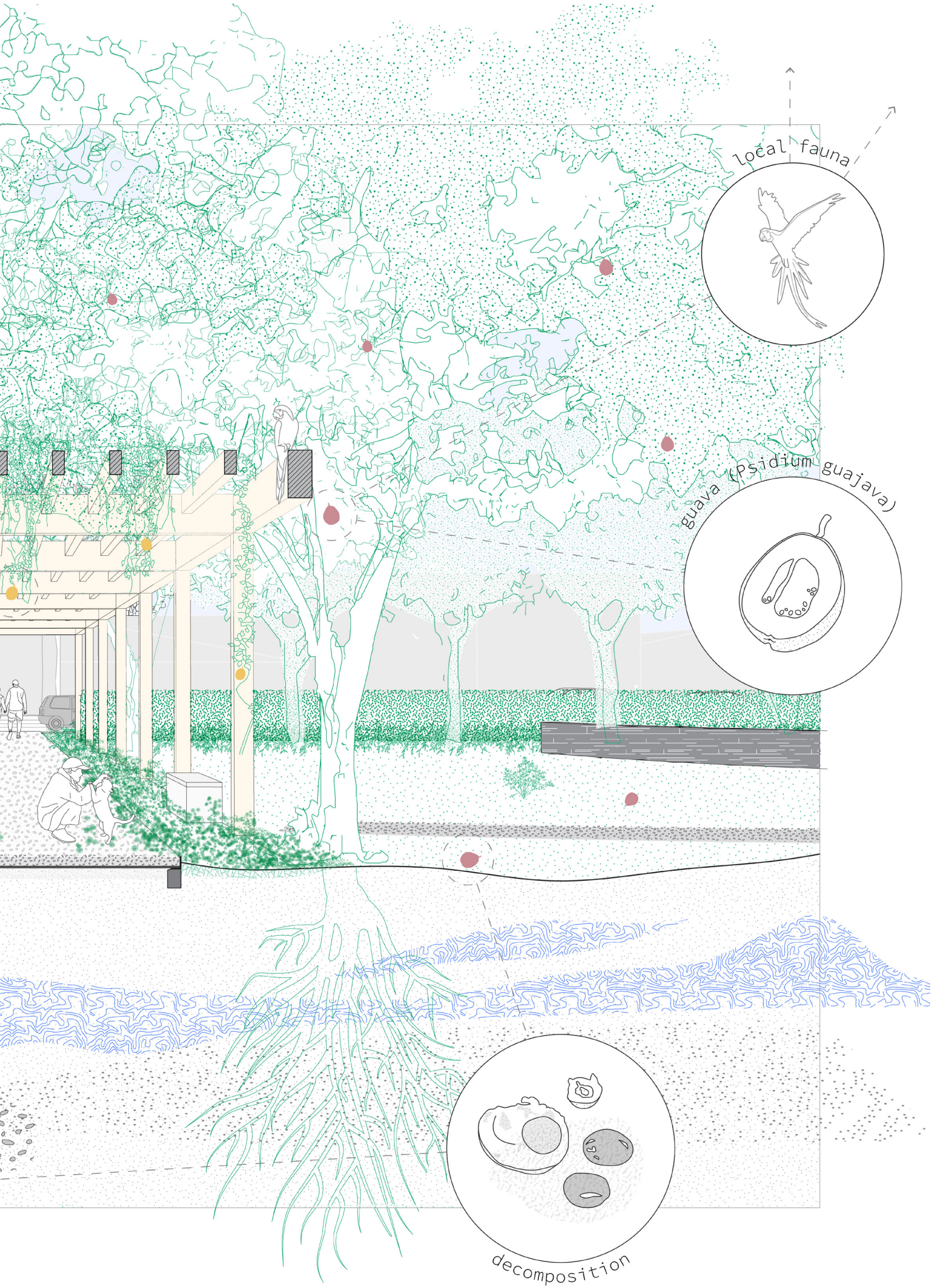









passionfruit (Passiflora edulis)
pequi (Caryocar brasiliense)
pollinators
water retention
soil life


local fauna
guava (Psidium guajava)
decomposition

04.05 Zoom-in B: Slope

As the Onça stream goes towards the Paraná River, it crosses a steeper region where contour planting is implemented. Since the area is close to the main city of Três Lagoas and close to the framework of the Paraná River, the space within the rows of planting should be filled with permaculture and agroforestry in smaller properties.

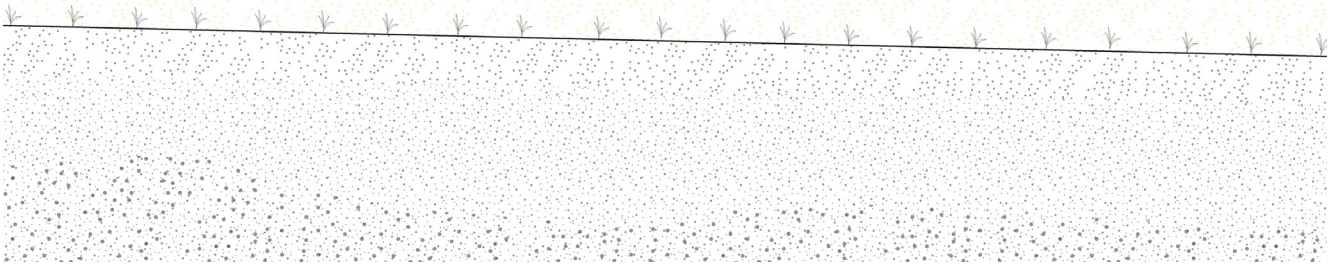
The first step in the planting along the contours is to dig part of the topsoil, forming a ditch, and use the debris to create a mound in the slope, to catch and hold rainwater. The topsoil in this region is highly contaminated with seeds of invasive species, and by digging and revealing a deeper layer, a first group of native pioneer species can be planted, using species such as Trema micrantha, Cecropia spp, and Solanum granuloso-leprosum, which can thrive in large gaps with a lot of solar incidence (Lorenzi, 2002). After the first irrigation, a layer of a cellulose-based tight mesh is applied around their trunks, holding the water for longer and minimising the need for more irrigation.

Once the rainy season comes, the rainwater runoff starts to accumulate in the ditch, which activates the seed bank, making seedlings of climax native species appear. They can only grow because the pioneer trees cast shadow on them, because the climax species are usually not sun-tolerant. Slowly, as the vegetation matures, gap-opportunistic understory shrubs and other forages also start sprouting, and the biotope becomes multi-layered and diverse. The root system holds the soil in place, keeping the system stable, but also tending towards a terraced landform as sediments accumulate.

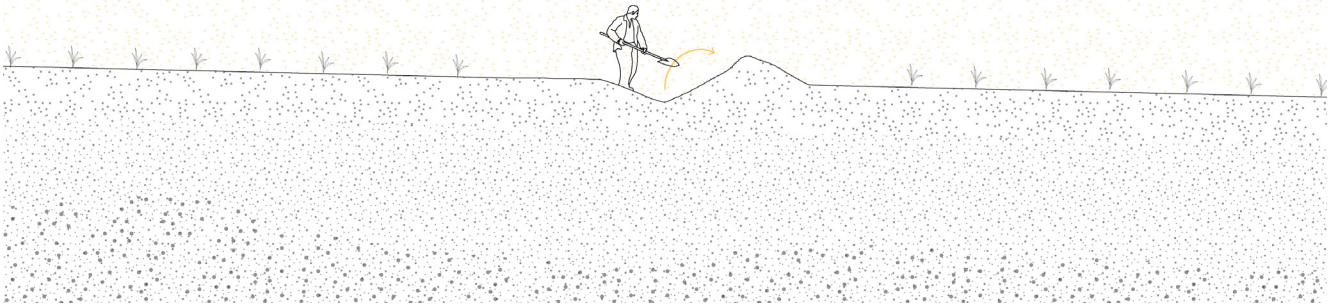
One of the characteristics of the Plantation model is the loss of the region's autonomy, because it only produces a limited variety of commodities for exportation, which also means that all flows are unilaterally outgoing. For example, studies show that the area equivalent to sugar cane plantations is bigger than the sum of the areas used to produce the components of the basic Brazilian meal: rice, beans, manioc and wheat (Bombardi, 2017, cited in Guimarães and Mendonça, 2019). In a condition with rampaging climate uncertainty, building a resilient landscape involves strengthening autonomy, creating circular cycles of nutrients that stay in the place. The slopes can be an opportunity for autonomy, with rows of farms producing food for the nearby cities, scaling flows from a global market scale to a local scale. As there is more human presence in this slope because of the permaculture workers, there is also a necessity for spaces where they can rest, which can be designed in a way to provide an intimate experience of familiarity with native flora and fauna.

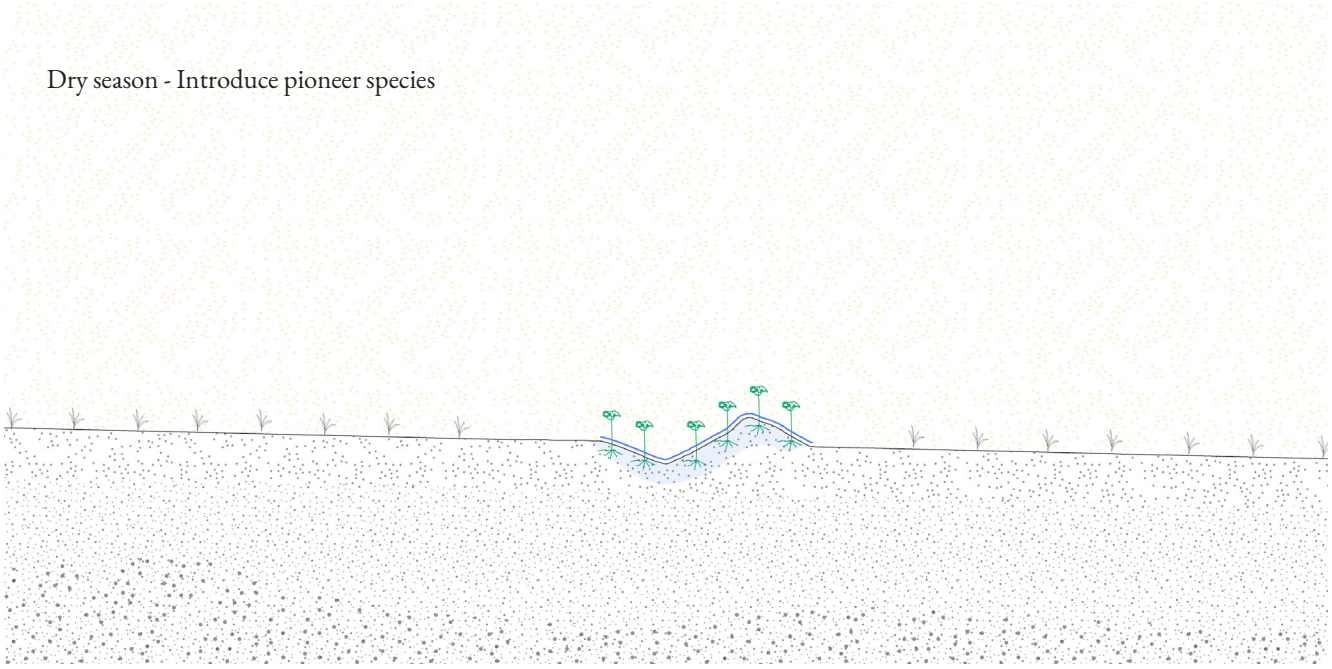
Agroforestry can be a way to create transition gradients, negotiation space, that offer opportunities for local inhabitants whilst protecting the ecological framework. Ernst Götsch migrated to Brazil 40 years ago and has been experimenting with what he coined as Syntropic Farming (Götsch, 1997), a method with successful outputs in different Brazilian biomes and a growing body of practitioners. It consists of recovering forest environments in degraded agricultural lands, while also enabling food production that is adapted to local ecosystems. It achieves so through three main principles: high biodiversity, stratification, and dense soil coverage. Syntropic agroforests consist of groupings of diverse vegetal species that cooperate well with each other, generating a process of natural succession where there is growing complexity and robustness of the system. They are usually vertically conceived with a high, a medium and a low strata, creating interdependencies connected to sunlight protection and water retention. Species can be introduced because of their positive impact on the system, which means that they are sometimes exotic or not economically interesting by themselves. For example, eucalyptus trees can be introduced for their fast growing capacity, allowing shade-loving species such as coffee to grow underneath. The system tends to autonomy in terms of fertilisation and the water cycle - in fact, irrigation is discouraged, because plants should adapt to local natural conditions. Human agency is present in trimming leaves and trunks and placing them on the soil, to retain water and stimulate organic matter to grow. Trimming is also a way to manage sunlight input, if a certain sun-loving species is desired to develop.

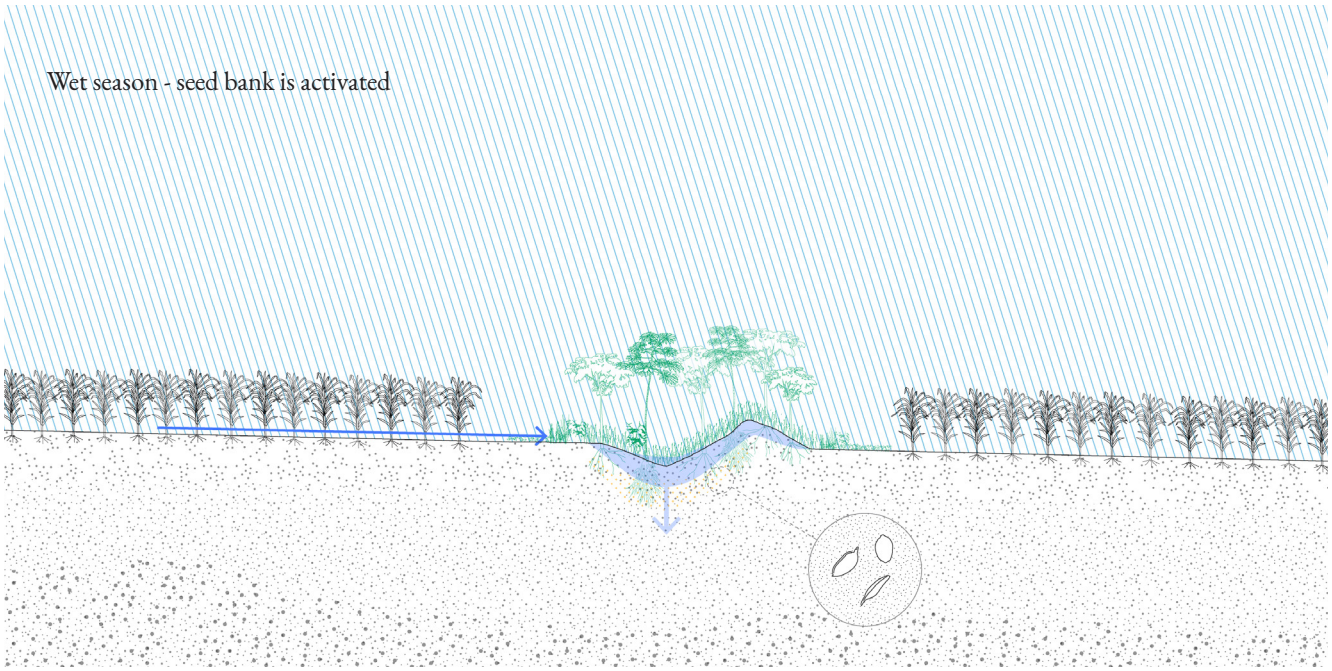
Dry season - Current situation



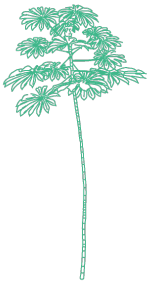
Dry season - Dig top soil to form a ditch



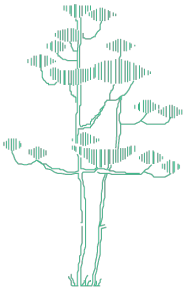




Trema micrantha

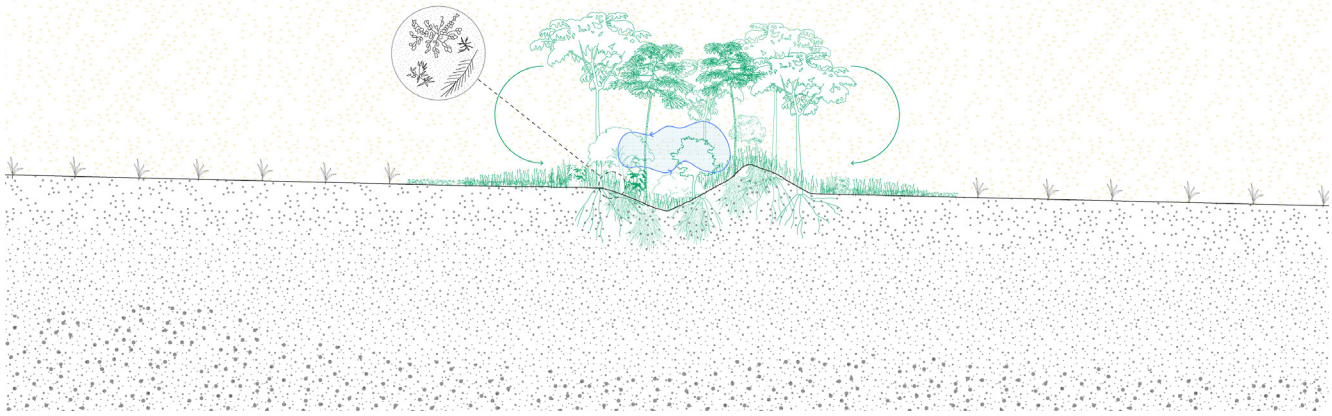


Cecropia spp.

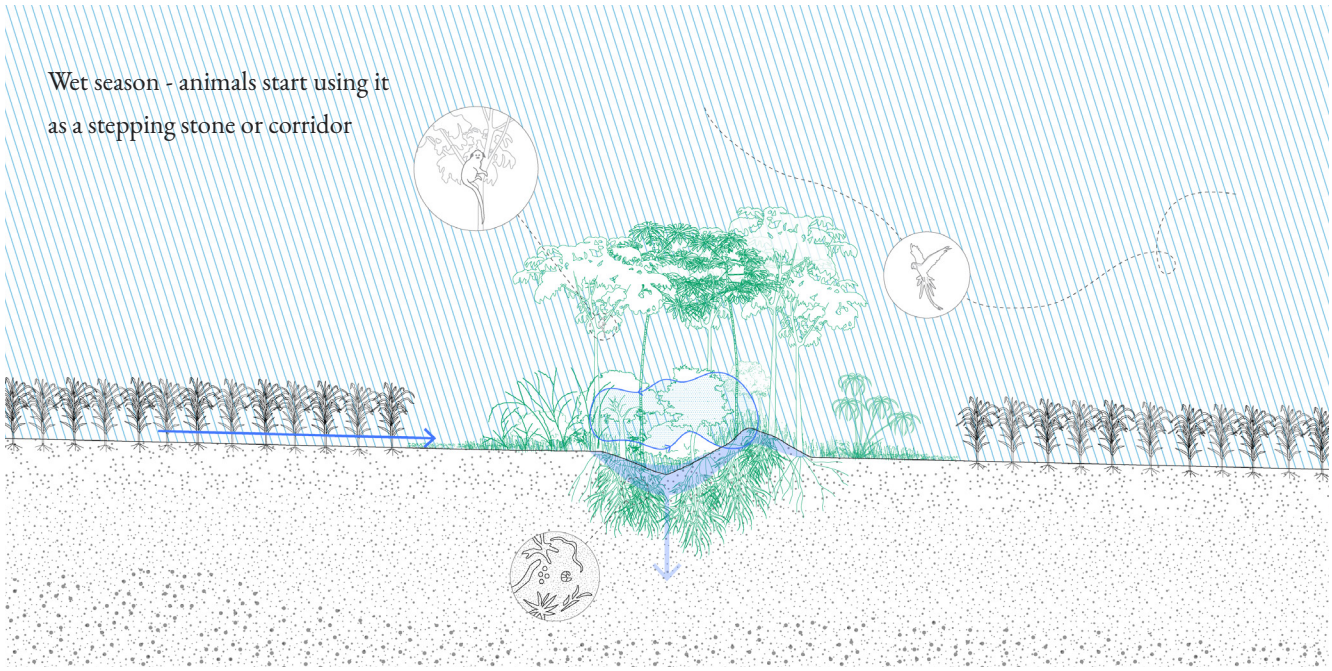


Solanum granuloso-leprosum

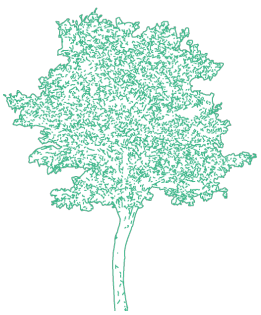
Dry season - Climax native species sprout



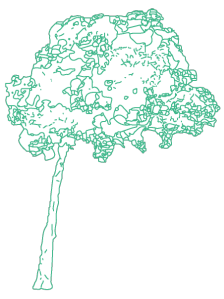
Wet season - animals start using it
as a stepping stone or corridor



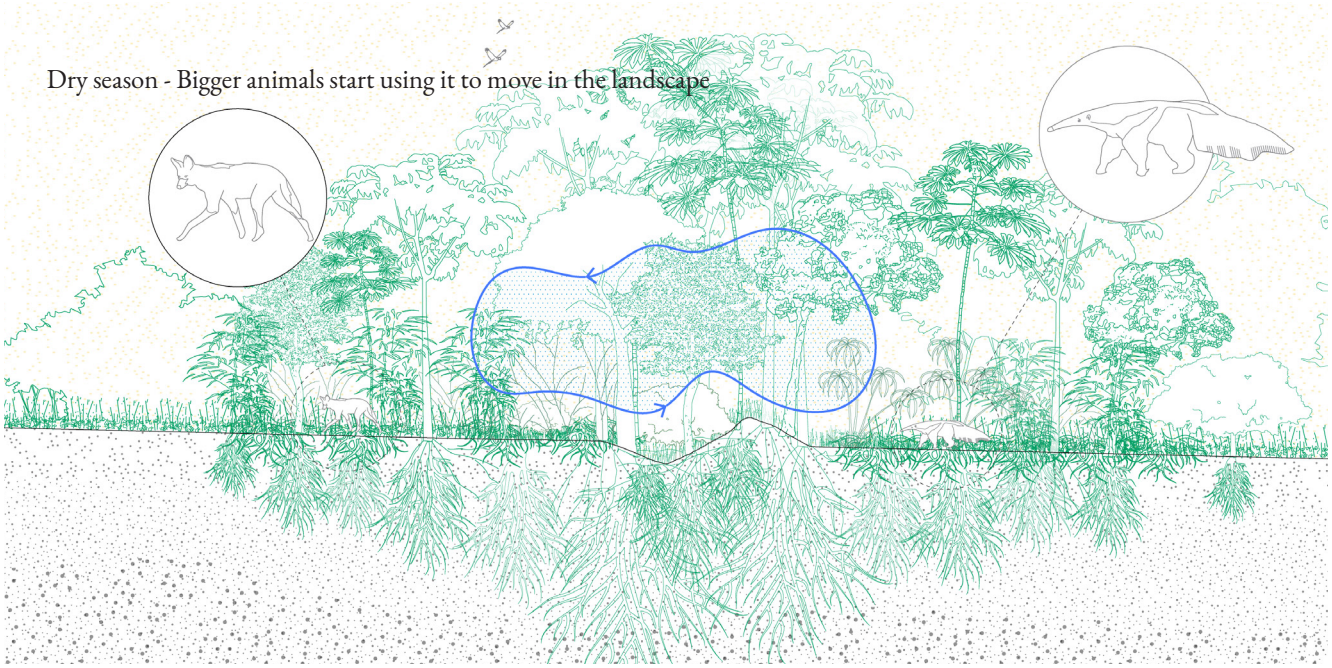
Jatobá

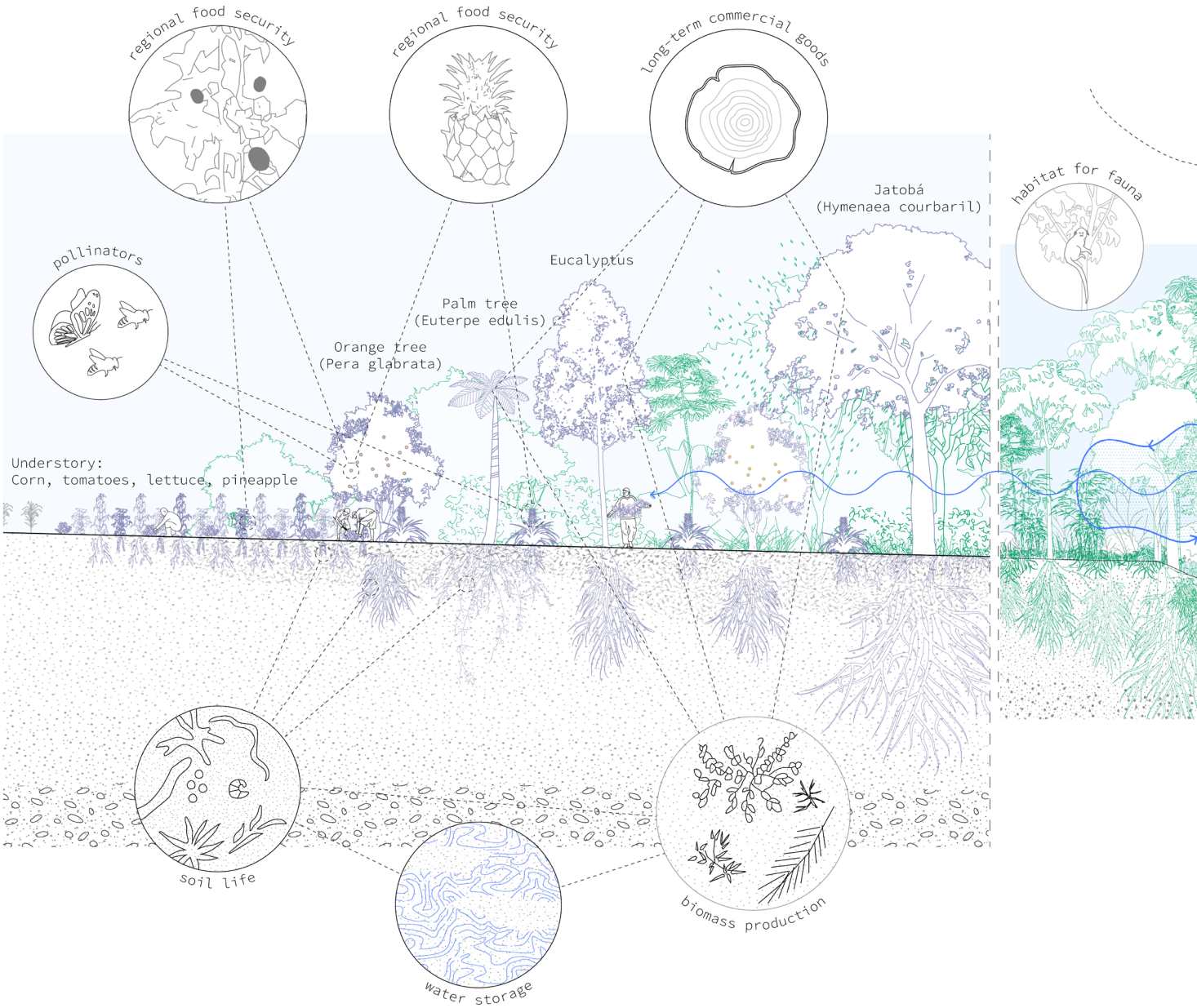


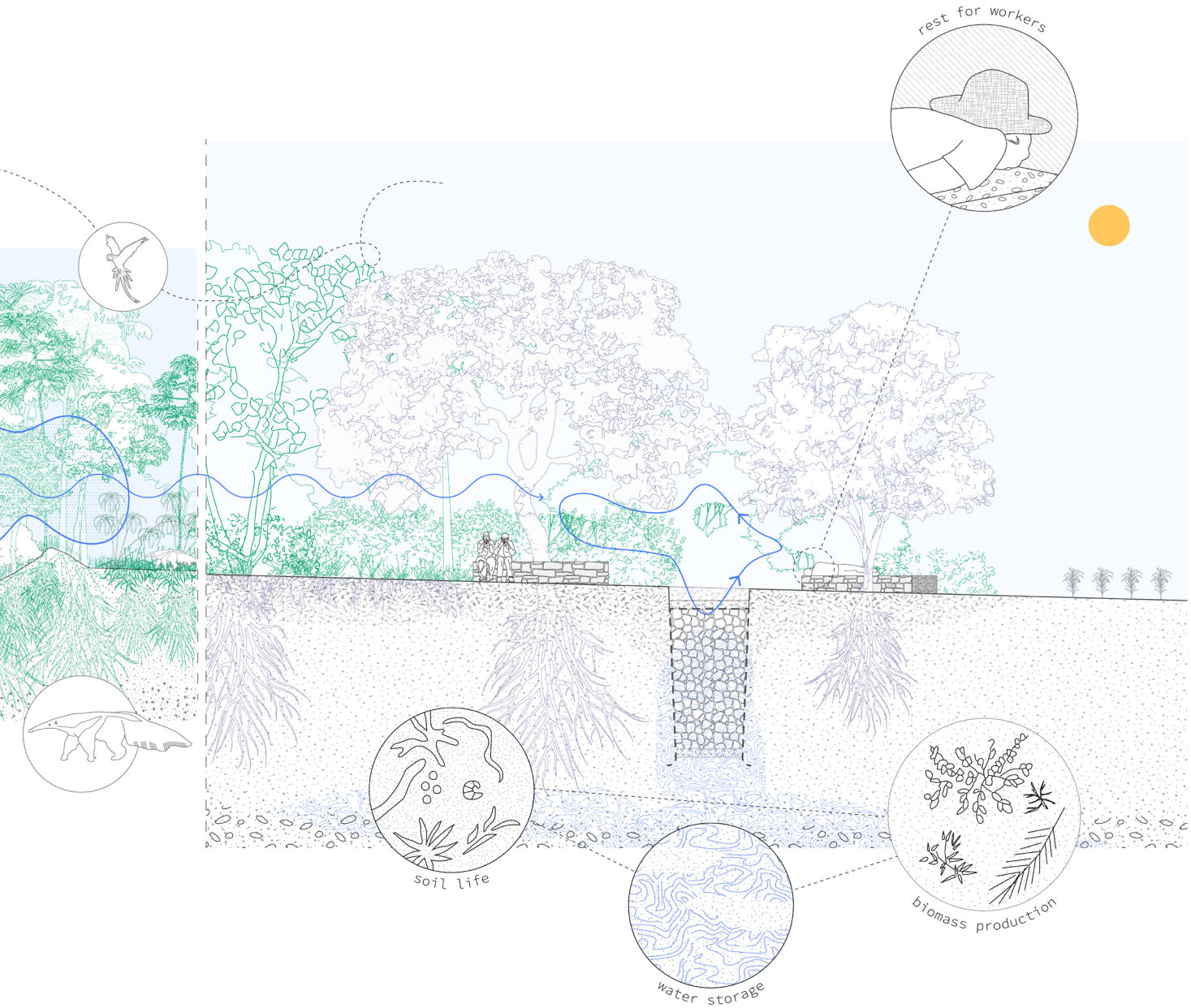
Peroba rosa



Ipê branco


Dry season - Bigger animals start using it to move in the landscape


regional food security
regional food security
long-term commercial goods
habitat for fauna
pollinators
Jatobá
(Hymenaea courbaril)
Eucalyptus
Palm tree
(Euterpe edulis)
Orange tree
(Pera glabrata)
Understory:
Corn, tomatoes, lettuce, pineapple
soil life
water storage
biomass production


rest for workers
soil life
water storage
biomass production

04.06 Zoom-in C: Flatlands

The final stretch of the Onça stream reaches the Paraná River, crossing an area defined by the regional plan as marshlands to be restored. Such restoration is done by constructing a bypass of the main river, with associated retention lowlands where different lagoons are formed. This marsh formation is composed of different degrees of connectivity and resulting biotopes that aim to re-implement the region's original riverine ecological value.

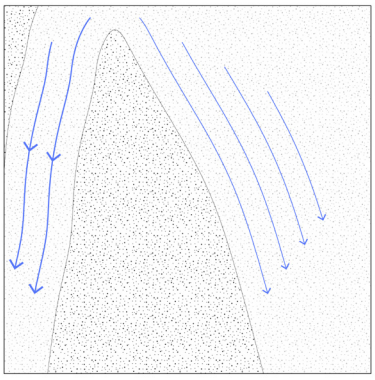
Currently, leisure activities along the Paraná River replicate a seaside typology, where sandy artificial embankments are created and occupied with palm trees, beach chairs, small buildings for bars, and slides. While this model is of high cultural value for the community, it is not inserted within the original dynamics of these margins. It was marshy and full of lakes and aquatic plants, a paradise for birds and fish. The challenge in this zoom-in was to imagine an ecologically-aware typology for leisure on the Paraná River's banks.

The first design strategy was to create a bypass, to regenerate the marshlands, forming a solid framework for the Paraná River. The island formed between the bypass, and the main body of water is the chosen ground for the marshland, whose formation probably depends on the implementation of barriers and embankments that steer the water in and organise its flows to form different biotopes. Experiments were undertaken at the Department of Water Management of the TU Delft to understand how such barriers and embankments should be arranged.

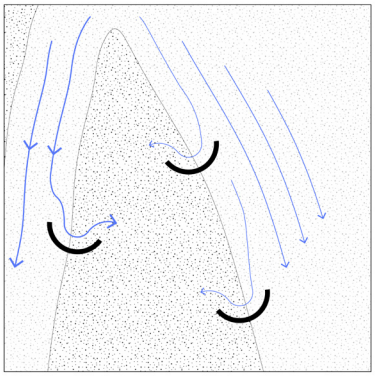
The first experiment happened on the 9th of June with the assessment of Dr Ir. Olivier Hoes. The soil was collected from the Verdronken Land van Saeftinghen, a marshland in the south of the Netherlands. According to Olivier Hoes, this soil was the most adequate for the experiment because it is the most untouched riverine sediment in the Netherlands. A series of tests were made with hypothetical barriers to observe how they changed water flows and how those subsequently sculpted the soil. The principles learned can be assessed in the diagrams.

The second experiment happened on the 14th of June and consisted of a site-specific application of the principles learnt in the previous session, now arranged according to design intentions. From a land-forming point of view, the area between the bypass and the main body of the Paraná River was conceptualised as a gradient between two goals: leisure and ecologically-rich marshland. The marshland area aims at creating various lakes of varied

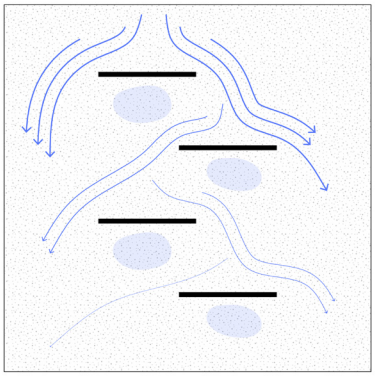
depths and water speeds, so it collects water from the main body of the Paraná River because it comes at slower speeds. Such flows are then steered by shapes that, according to the first experiment, absorb their momentum, creating spaces of calm water. The leisure areas are formed mainly by a canal that crosses the “island” and whose speed is intentionally accelerated to keep it free from sedimentation and silting up. The endpoint of this canal is a generous retention basin where people can swim.



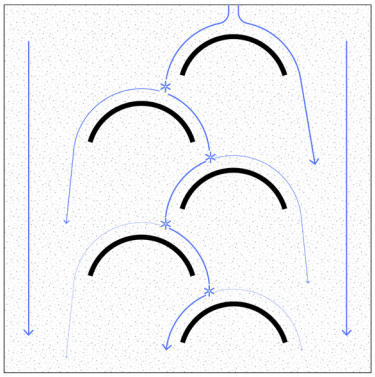
01. The water in the bypass goes quicker than in the broader river. A higher island does not get affected by the flows.



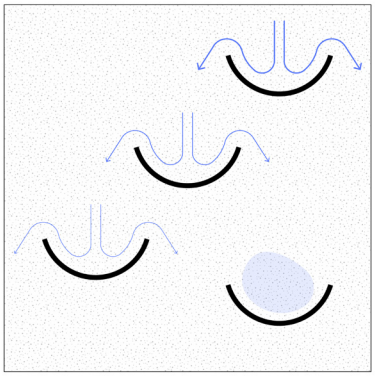
02. Elements aimed at bringing the water in should be half placed into the water. Flows from the bypass come with more momentum



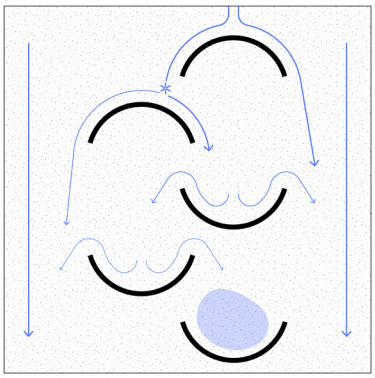
03. Horizontal elements cut the flows' momentum, creating a homogeneously wet and calm environment behind.



04. This configuration makes the water go faster, because it has smaller gaps to cross. Prevents silting up of canals.

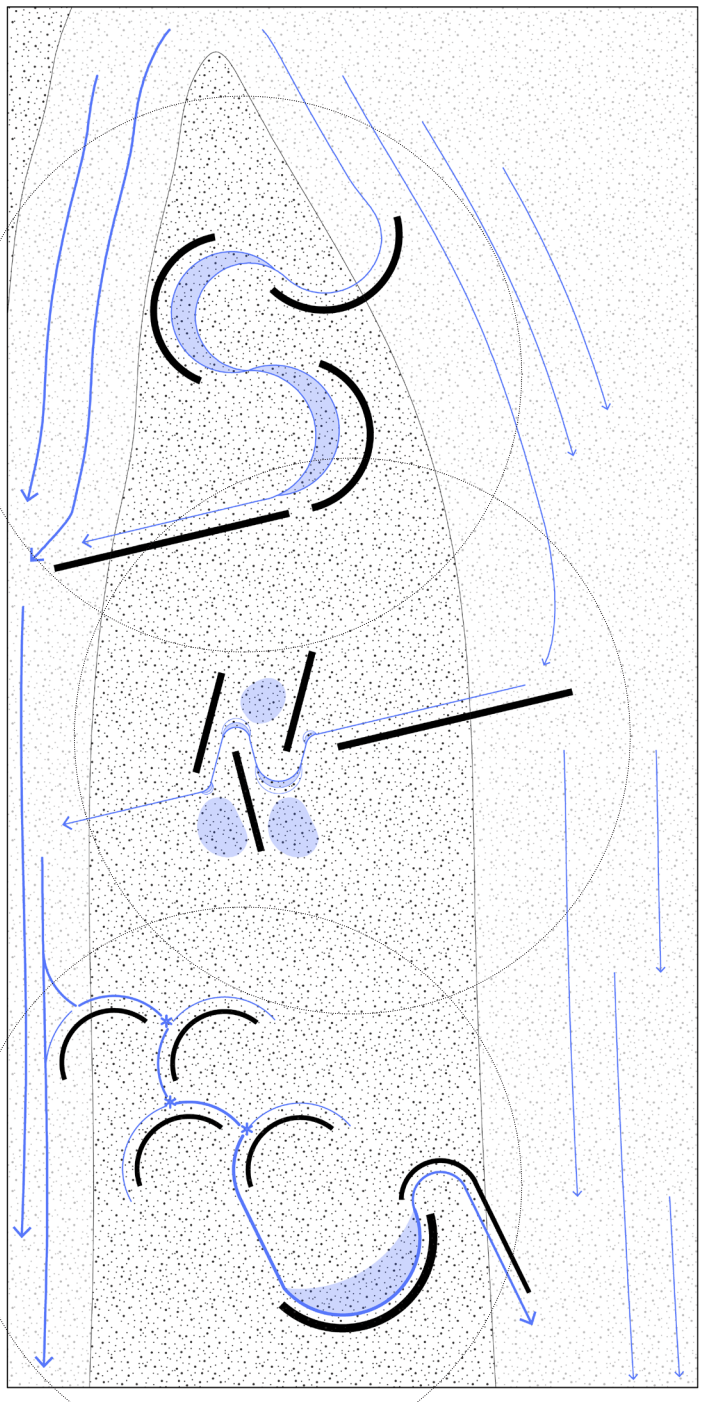


05. This configuration absorbs the energy of the flows, generating a calm lagoon in the back.



06. Combinations can create balance between un-silted canals and calm environments.

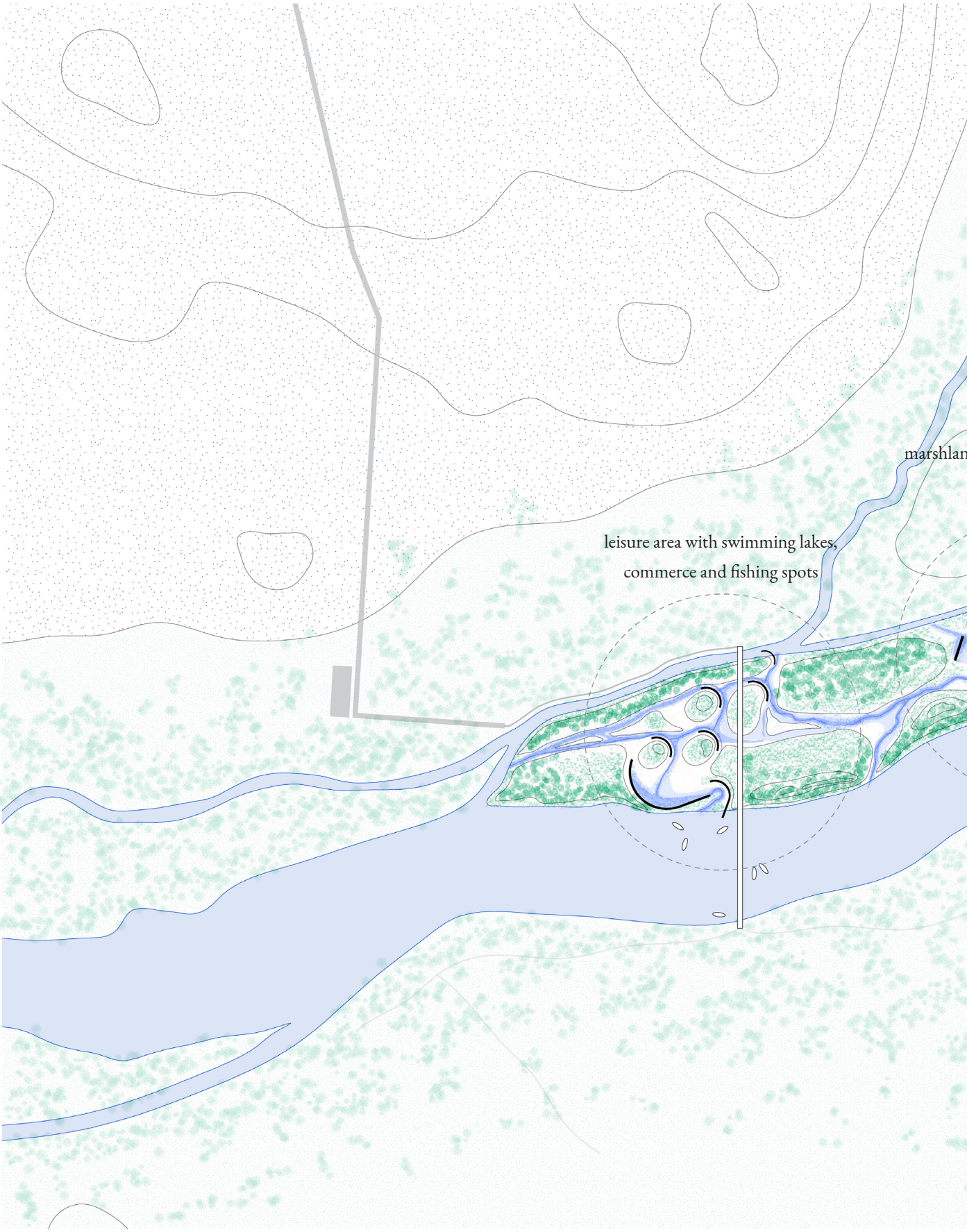
APPLYING PRINCIPLES WITH DESIGN INTENTIONS

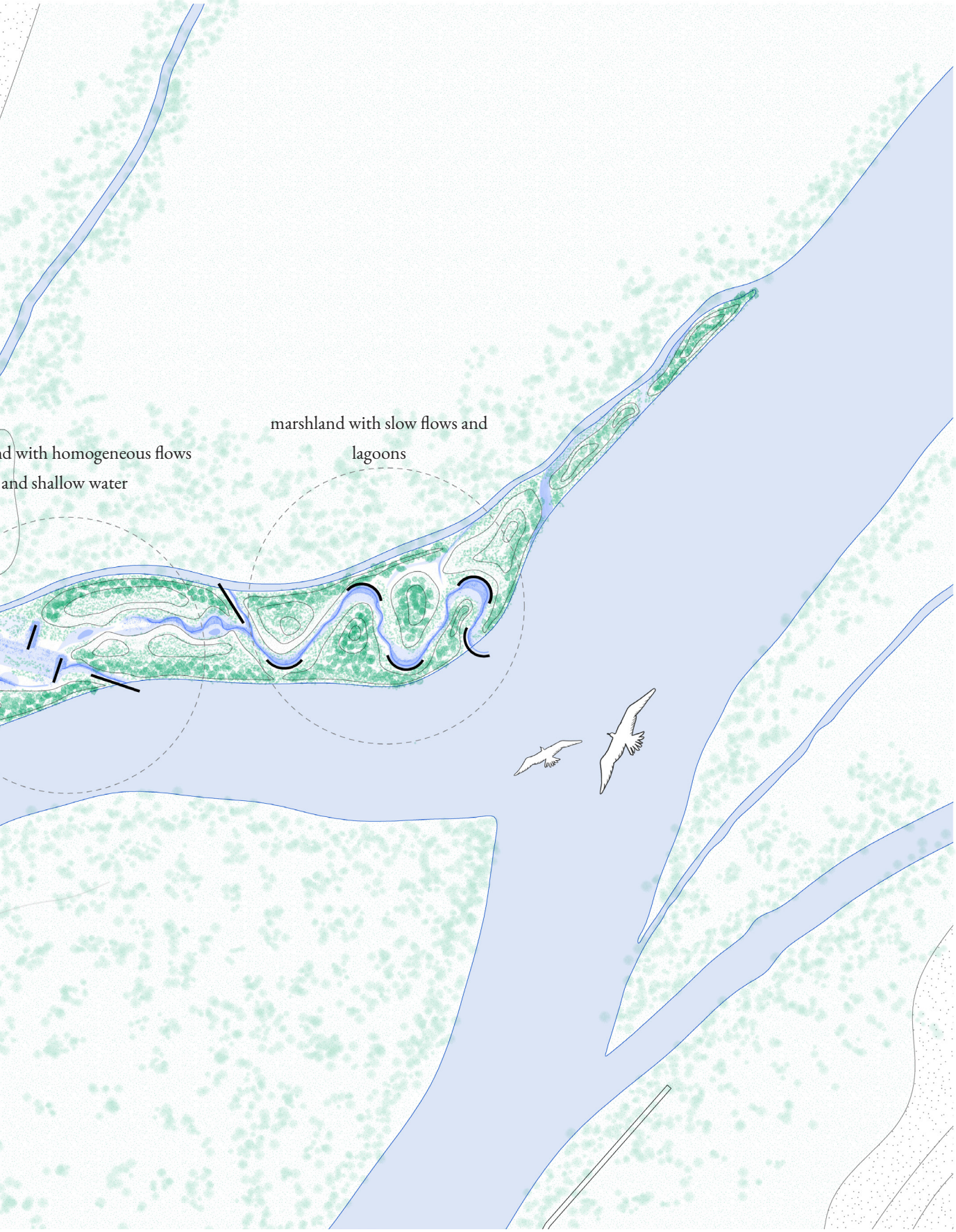


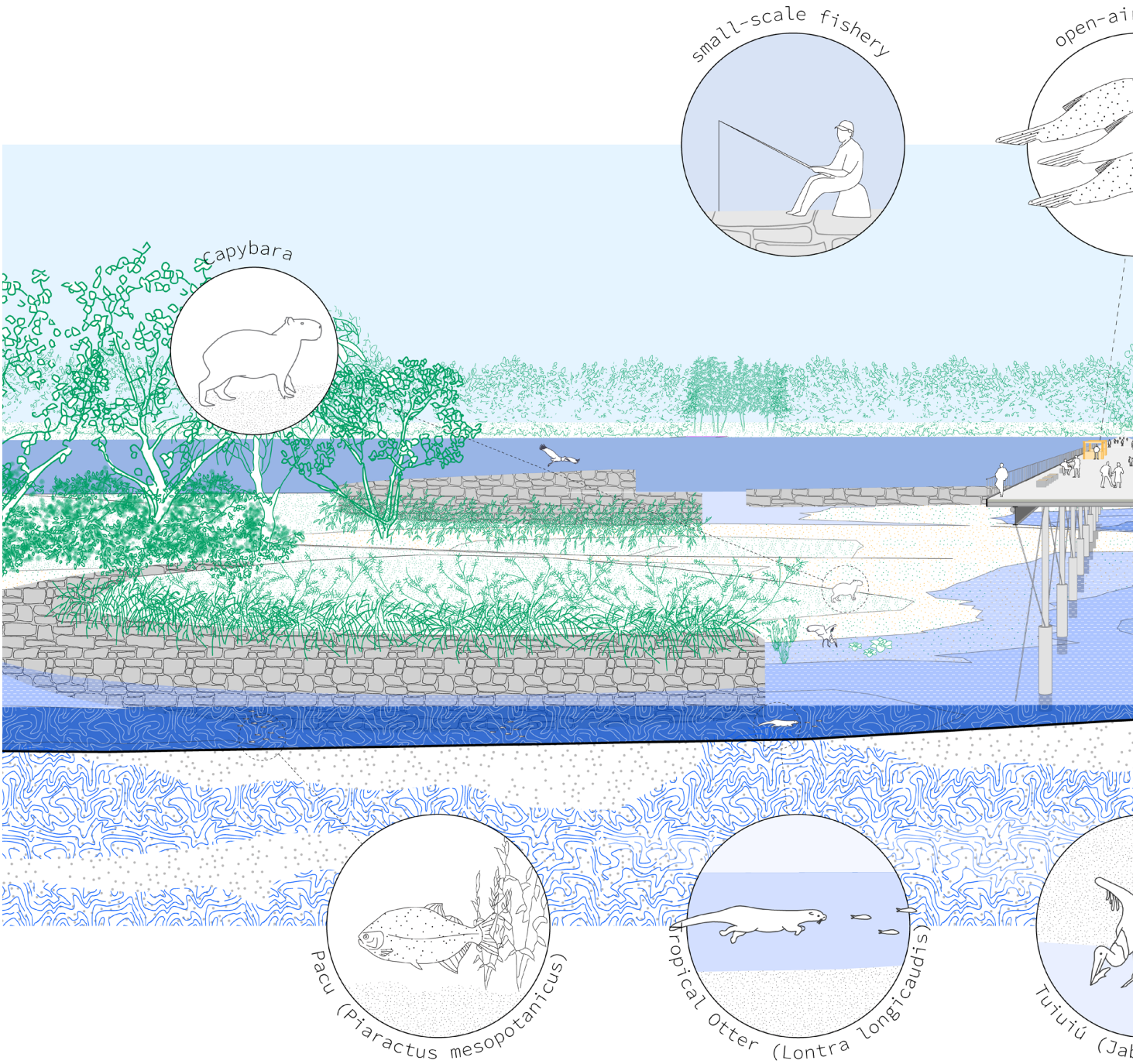
01. Energy-absorbing structures create a slow and calm canal with lakes.

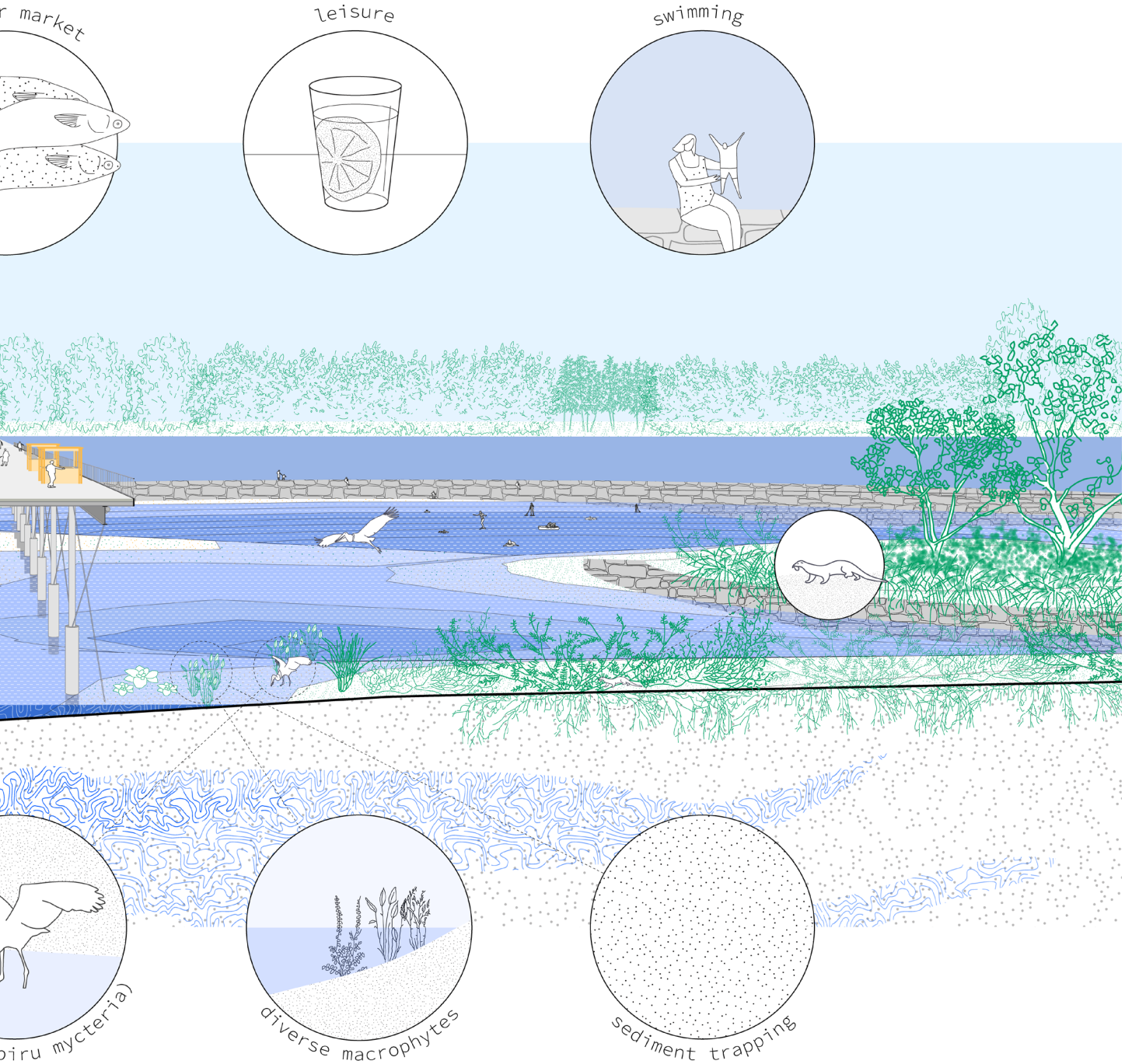
02. Horizontal structures create a homogeneously wet environment

03. A series of bottle structures generate a stronger flow, keeping the canal free from silting up. It ends at a retention structure, which could be a swimming venue.


marshlan
leisure area with swimming lakes,
commerce and fishing spots

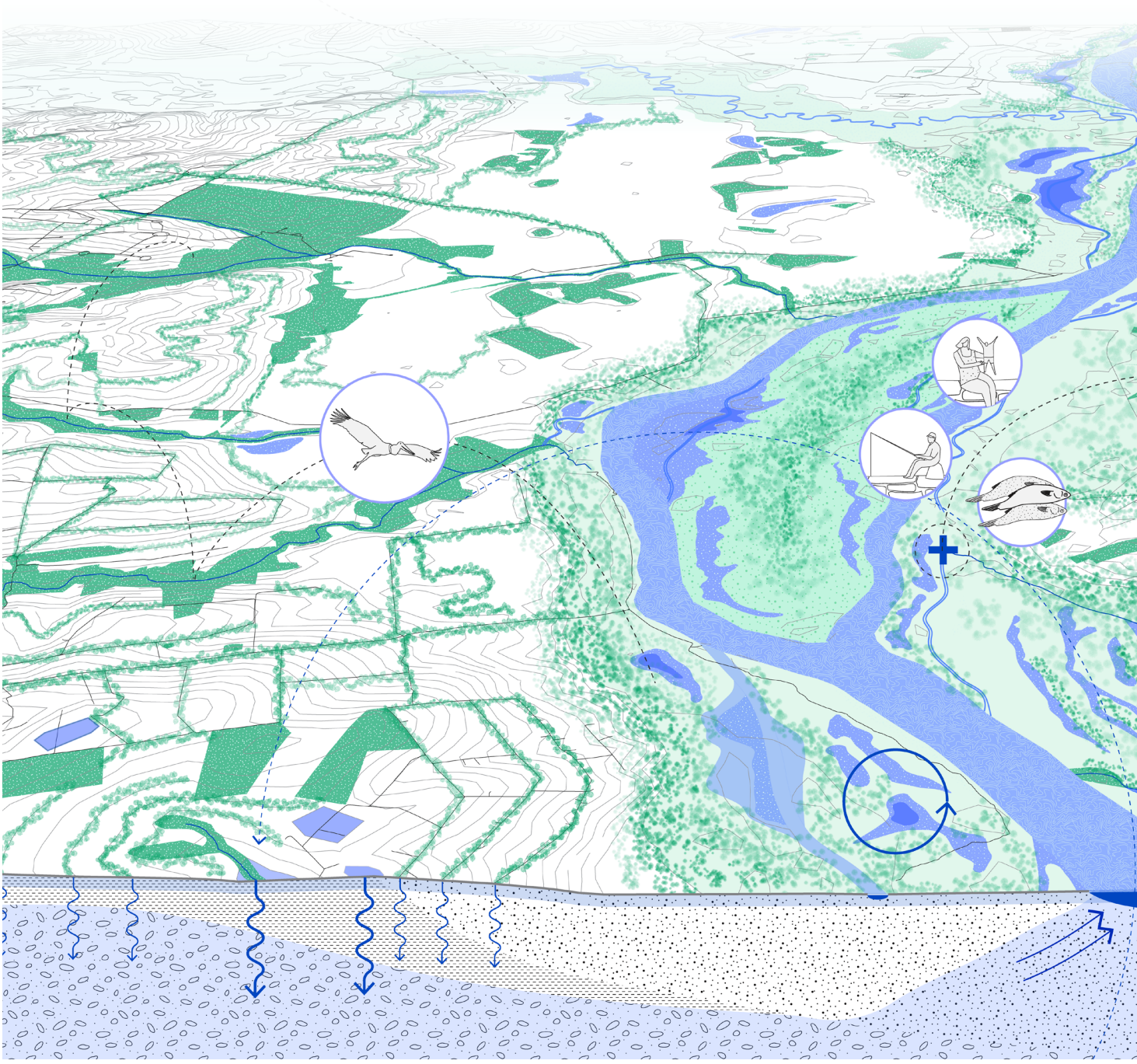

marshland with slow flows and
lagoons
d with homogeneous flows
and shallow water


small-scale fishery
capybara
Pacu (Piaractus mesopotanicus)
Neotropical Otter (Lontra longicaudis)

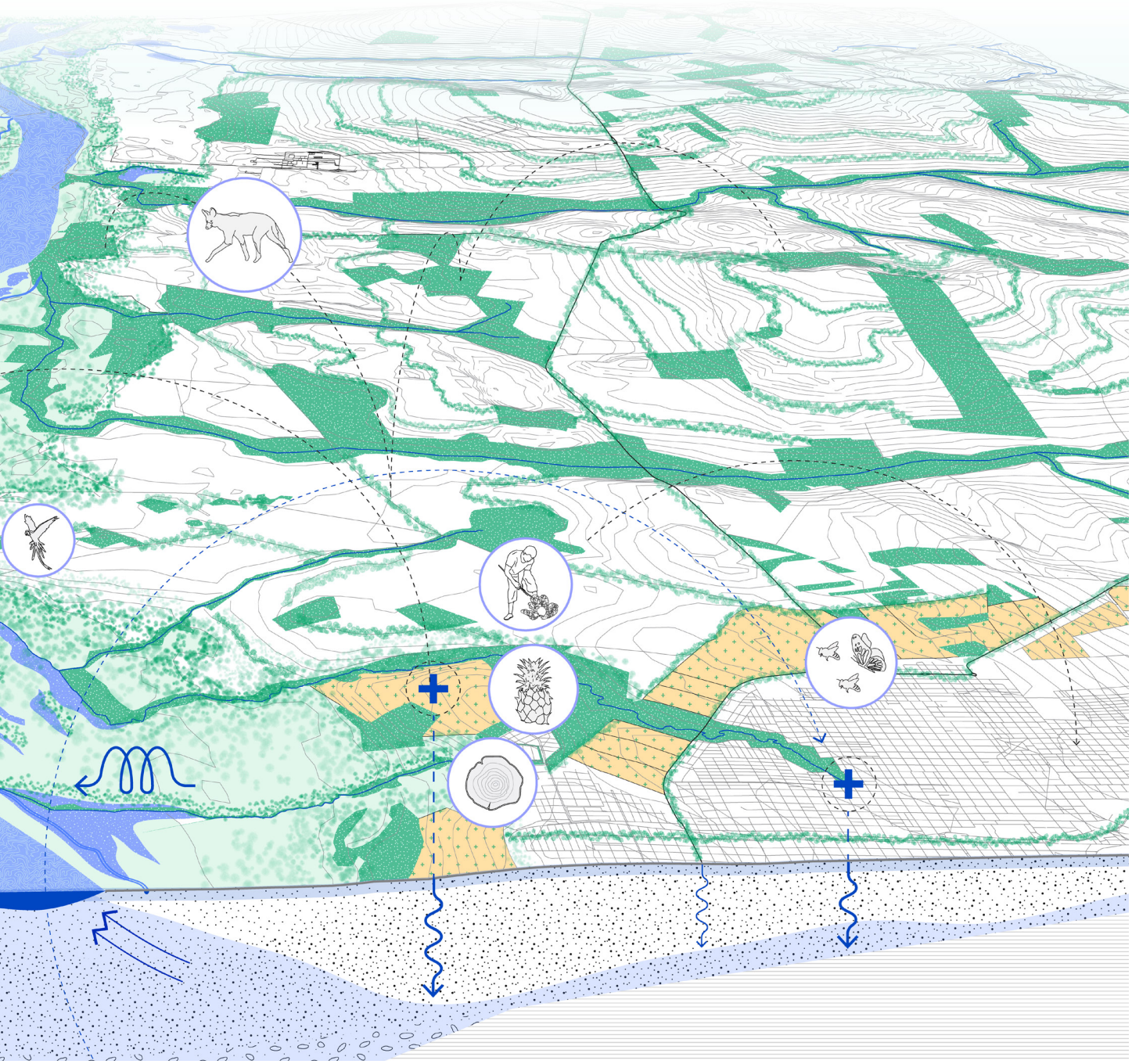

r market
leisure
swimming
piru mycteria)
diverse macrophytes
sediment trapping

04.07 Conclusion: a Systematic View

Even though each of the three zoom-ins into the regional plan are autonomous spaces, their belonging to a common framework entails working together as parts of a system. The goal is that each one of them performs positive functions for a healthy hydrologic system while being enriched with ecological and social values. Zoom A proposed a design for an urban square with a park design that assures protection to a water spring, where the aquifer is very exposed, while also making it accessible to the public as a landmark for the city. Zoom B consists of a stretch of contour planting associated



with permaculture, which fosters autonomy by enabling food production and rest for workers in the agricultural industry. The ditches in the contour planting system, associated with a rich root system and many vegetal strata, strengthen infiltration to a deep level, recharging the Guarani Aquifer. As for the water runoff flowing from the surface of the slopes, a regenerated system of marshlands and dynamic lakes makes water residence times much longer while reinforcing one of the prominent original roles of the Paraná River: an ecological migration corridor crossing an extensive part of South America.



05. Developing a Position in Landscape Architecture

In his influential text “An Ecological Method” from 1967, Ian Mcharg claims that one of the most considerable virtues of the Landscape Architect is to bridge the natural sciences and spatial design as a discipline that is on the edge between science and art. The original motivation behind this research was to understand how Landscape Architecture as a discipline could contribute to tackling the issue of drought, which later expanded to hydrologic disbalances in general. The research question states: “How can adaptive spatial design, developed upon a landscape architecture approach, enhance water retention and resilience in the UPRB in the light of drought and uncertain future challenges?”

The first reaction to the idea of retaining water might be to build high-capacity reservoirs, but the fact is that they already exist in the form of dams, and the system is disrupted even so. A dam is a highly punctual type of infrastructure that does not adjust to local existing ecological processes; on the contrary, they usually disrupt them (Metcalfe et al., 2020). A different approach would have been to conceive dams in accordance with the landscape and, on the other end, to conceive the landscape as a type of infrastructure - infrastructure as landscape, landscape as infrastructure (Nijhuis & Jauslin, 2015). Wide-scale climatic shifts can only be effectively addressed if the whole landscape can act as a web of performative spaces, which is especially strong in the case of water cycles since wetness is everywhere (da Cunha, 2018).

Working at a territorial scale in regional design is one of the many roles of Landscape Architecture - even though this would and should never happen without the active participation of other disciplines and actors outside of an academic environment because space is where all interdisciplinary knowledge has to be synthesised. The aim should be to equip the region with robust frameworks and spatial armatures that allow ecological processes to continue but can negotiate and adapt with social and cultural layers in mutually beneficial ways. The Landscape Urbanism approach and the Ecological Method by Ian McHarg posit that the biophysical layers of the landscape should be the basis for human developments, which would be offered adequate conditions. This research agrees with this statement, keeping in mind that design is an ontological practice that emerges from culture and defines ways of living (Escobar, 2018). That means that the decision to provide a spatial framework for ecological processes to happen is full of a certain positioning - which responds to a zeitgeist of climate emergency, exhaustion of resources, and uncertainty about the future. This

is potentially related to McHarg's statement on the connection between Landscape Architecture and art; the discipline bears the responsibility of setting conditions for human and more-than-human living, for good but also for bad, as in the Plantation model.

Finally, the changes in scale, from regional to very local, were a spontaneous consequence of the investigation and say something about Landscape Architecture as a discipline. The idea of landscapes as a space continuum establishes a correspondence wherein what happens locally impacts ecosystems and biophysical and human processes at a broader scale, and vice versa (Bobbink & de Wit, 2020). Therefore, it is part of climate resilience that strategies exist at very different scales, from a regional armature to small-scale designs that can retain water and promote cultural knowledge of the biome within which it is located. Landscape architecture can help people learn about their territory, its biomes and processes, and how to care for it.

Zooming into a regional framework means depicting how it works at a small scale, but it does not mean that the designs are purely a consequence of the framework. The combination of many designs generates a more or less robust framework, depending on the amount and aspect of the combined performative spaces. That implies that each small-scale design should work by itself; each zoom-in is already contributing to re-establishing the hydrologic cycle regardless of the existence of the rest of the framework.

To conclude, the limitations of the discipline must be acknowledged, especially when it comes to the extension of the issue of climate change. Spatial design can prepare the landscape to withstand the disturbance and aim at doing so in a way that the causes of the problem - in this case, the destructive functioning of the Plantation model - are addressed, with the idea of a scale continuum as a potential background for optimism.

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