ECOLOGICAL DESIGN: STRATEGIES FOR THE VULNERABLE CITY

Adapting Precarious Areas in Latin America and the Caribbean to Climate Change

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& Jeannette Sordi
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According to the United Nations, approximately three in five cities in the world with 500,000 residents or more are at high risk of natural disaster. If the task of mitigating and adapting cities is not undertaken, in the future these cities will become more populated, hotter, and less biodiverse. The environmental and climate crises accentuate inequality, given that socially and economically vulnerable groups are more exposed to natural risks and generally have less access to infrastructure and ecosystem services. In Latin America and the Caribbean, the most vulnerable populations often reside within informal, precarious, or low-income settlements. In recent years, there have been important advances in rethinking these settlements, with the development of urban design and planning strategies to improve the quality of life, safety, and opportunities for their population. Today, it is essential to effectively incorporate climate criteria into these interventions. Ecological Design measures the impacts of the climate crisis in the most vulnerable areas in the region, the informal city, and looks at design and planning solutions to protect those who are most affected by the consequences of climate change. The book provides new lenses through which to analyze risk and implement nature-based solutions in precarious, informal, and vulnerable urban settlements in order to create a more resilient city in the face of the coming decades of climate pressures.
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Ecological Design: Strategies for the Vulnerable City Facing the Climate Crisis

The large demographic flow toward cities, which has been ongoing for the last decade, reflects the aspiration and hope that cities can bring people a better future. Every year, the urban population grows at a global average of 67 million people. In 2020, the urban population totaled 3.9 billion, which is 55% of the world’s current population, and it is estimated that by 2050 it will increase to 6.4 billion, which is 66% of the world’s population. As centers of prosperity and innovation, cities are also largely responsible for the climate crisis and are affected by its consequences. Cities consume 75% of the energy worldwide and produce between 50% and 60% of greenhouse gas emissions.

According to the United Nations, approximately three in five cities in the world (with at least 500,000 inhabitants) are at high risk of becoming victims of natural disasters.
If we do not improve how we mitigate and adapt to the effects of climate change, cities will become more populated, warmer, and less biodiverse in the future. It is more urgent than ever to search for an alignment between natural processes that allow the environment and urban development processes to function. The environmental and climate crises accentuate inequality, given that the most vulnerable groups are more exposed to natural risks and have generally less access to ecosystem services, thereby increasing poverty traps. Globally, the richest 1% of the planet’s population owns 44% of the world’s wealth and emits greenhouse gases that are equivalent to the amount emitted by the poorest 50%.5 In Asia, Africa, and Latin America, almost 1 billion people, which represents one-sixth of the world’s population and one-third of all urban dwellers, live in informal settlements, unplanned settings, and substandard housing.6

According to the United Nations Human Settlements Program, UN-Habitat, it is expected that this number will double by 2030.7

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1.3 billion people live below the poverty line and, of these, 886 million live in middle-income countries such as those in Latin America, potentially leading to an increase in informal settlements.\(^8\)

In recent years, important advances in the rethinking of the informal city have been made in many respects. From a theoretical standpoint, there have been attempts to formulate a non-discriminatory terminology that accepts the spontaneous, kinetic, and precarious nature of informal settlements.\(^9\)

From a practical standpoint, there has been a growing interest in developing urban planning and design strategies to improve the quality of life safety and opportunities for their population.

Today, it is fundamental to incorporate climatic criteria in urban interventions in an effective way. It is now a recognized fact that the process of formal urbanization excludes the large number of people who have built their own homes in marginal areas of greater risk in cities and that they lack infrastructure and...
essential services. These conditions have now been further aggravated by climate change.10

The estimates predict that climate change will increase risk for people, resources, economies, and ecosystems. It has also been estimated that it is highly probable that landslides, thermal stress, extreme rainfall and flooding, water scarcity, erosion, and the sea level will all increase. Notwithstanding the efforts that cities are making in preparation for the incipient climate crisis, the poorest and most precarious neighborhoods are rarely included in the development of public policies, infrastructure, urban design solutions, and technologies. Faced with this challenge, architectural, urban, and landscape design have begun to offer solutions that can help cities, in particular the most vulnerable settlements, designing a future that is better adapted to the new weather conditions. The cities and their precarious areas are new ecosystems that can be designed. The great challenge facing the climate future is enhancing our capacity to imagine and design cities in a better way.

10. IPCC. (2014). Fifth assessment report of the United Nations Intergovernmental Panel on Climate Change. IPCC.
Since urban areas will have to reduce their emissions in the future, it is also important to explore our imagination and the potential that design has, assigning the central role to nature and ecological practices. This can generate meaningful changes in ways of thinking about the most vulnerable areas of cities. Ecological Design is a project that recognizes this reality and seeks to develop strategies of intervention that directly address deepening inequality as a consequence of the effects of climate change. This work measures the impacts of the climate crisis in the most vulnerable areas of our cities, the informal city, while reflecting on how to protect those who are most heavily affected by the consequences of climate change. In addition, it provides new lenses through which to analyze risk, as well as nature-based design solutions for precarious, informal, low-income, and vulnerable urban settlements, creating an informal city that is more resilient to the climatic pressures that will come in the next few decades.
"Ecological Juxtapositions" is a project developed for this publication by Inés Benítez Gómez. It is specifically aligned with efforts against urban inequality and climate change, building towards sustainable cities and communities in Latin America. Through these images, it seeks to communicate the horizon of understanding, sensitivity, and discourse that these topics require, on a more abstract level.
THE VULNERABLE CITY AND THE CLIMATE CRISIS: URBAN AREAS INCREASINGLY AT RISK
Cities are key players in the climate crisis. According to production-based figures, cities are responsible for 40 types and 70% of greenhouse gases. If we consider consumption, they are responsible for 60 types or 70%, which is to say greenhouse gas (GHG) emissions from the production of all the goods consumed by urban residents, regardless of their geographical point of production. It should be noted that the main sources of GHG emissions in cities correspond to the consumption of fossil fuels (coal, gas, and oil) not only for electricity generation, but also for transport, energy in commercial and residential premises, heating, refrigeration, cooking, and waste.

For example, only 17.5% of the total energy consumption in 2015 came from renewable energy. However, cities are also centers of innovation, the diffusion of ideas, as well as social values and therefore are also strategic places in terms of facing the climate crisis and rethinking the way we design infrastructure and city settlements in a more resilient and sustainable way.

Projects with multifunctional infrastructures are being developed in coastal fronts, green areas, and public spaces, which...
can help protect coastlines from rising water levels and flooding, limit erosion, reinforce the soil, and mitigate the effects of heat waves in vulnerable neighborhoods. Public spaces that can create collaborative communities that are prepared to respond to sudden events and changes over time.

Cities like New York, Miami, and Boston, for example, are investing billions of dollars to redesign their waterfronts, modify the infrastructure and existing neighborhoods, and implement new projects and policies.\(^6\) In recent years, these cities have been heavily affected by the climate crisis: Hurricane Sandy in New York, the constant rise in sea level in Miami, the combination of the two effects in Boston.\(^7\) The new infrastructures in urban areas have the objective of mitigating these effects and disruptions. They simultaneously generate momentum to improve the quantity of green spaces and the quality of life in the neighborhoods where they are implemented, rethinking mobility, attracting tourist flows, and generating new economies. However, not all cities have the same means and resources.

Most urban growth is occurring in developing countries where extensive portions of the urban population live in poverty and in areas that are vulnerable to extreme weather events. Cities in countries in the Global South are also more exposed to the effects of climate change, as seen in Map 01. This graph indicates the percentage of the population living in informal settlements and the country’s vulnerability to climate change. It is based on EM-DAT data from CRED (Center for Research on the Epidemiology of Disasters), with priority given to data from UN agencies. Factors shown relate risk to climate change and coastal vulnerability.\(^6\) The largest percentage of population living in informal settlements, and the country’s vulnerability to climate change is in situations of informality and precariousness, slums and unplanned neighborhoods, these impacts can even compromise their survival. In Asia, Africa, and Latin America, almost 1 billion people (equivalent to one-sixth of the world’s population and one-third of all urban dwellers) live in informal settlements, unplanned settings and substandard housing.\(^8\) According to the United Nations Program for Human Settlements, UN–Habitat, it is expected that this number will double by 2030.\(^9\) Today, 1.3 billion people live below the poverty line and, of them, 886 million live in middle-income countries like Latin America, feeding informal settlements.\(^10\)

Paradoxically, although the informal settlements contribute little to greenhouse gas emissions, they are the most vulnerable group to the impact of climate change. It seems to be a recurring phenomenon within cities that those that have a lower capacity for consumption and therefore are responsible for a far lower amount of emissions are often the ones that most suffer the consequences of climate change.\(^11\) Also at the global level, countries with higher GDPs are often the countries responsible for the highest amount of GHG emissions and the less vulnerable to climate change. The countries that are the most vulnerable to climate change are also those with the largest percentage of population living in informal settlements, especially in Latin America.\(^12\)
Not all cities have the same means and resources. The highest rate of urban growth is occurring in developing countries, where ample portions of the urban population live in poor conditions in areas that are vulnerable to extreme climate events.

Source of informality data: UN DESA Statistics Division, 2018: Proportion of urban population living in slums (percent) Series Code: EN_LND_SLUM https://www.sdg.org/datasets/f158f819bd284fd5b35e456a152a069c0?geography=71.896,-77.655,-69.432,75.629

The relation between emissions and effects raises issues of equity and justice and establishes the need to prioritize finding solutions that can level out the resilience of the poorest neighborhoods in a sustainable way. These solutions should also address the need to improve the quality of life in the settlements, connecting them with or integrating them into the city, and anticipate future developments. Every year, the global urban population grows by an average of 67 million.19 People who live in cities will be increasingly vulnerable to the effects generated by climate change and rising temperatures, such as greater intensity and frequency of extreme weather events like floods, droughts, waves of heat and cold, gradual rising sea levels, and acceleration of the processes of desertification, erosion, and loss of biodiversity. According to the United Nations, about three out of every five cities of the world with (at least) 500,000 inhabitants run a high risk of suffering a natural disaster.19 Map 02 shows the global urban population of cities with more than 1 million inhabitants, and their growth in 1950, 1975, 2000, and projections for 2035. In 2020, the urban population rose to 3.9 billion, which is 55% of the world’s population. In 2050, it is estimated to increase to 6.4 billion, which is 66% of the world’s population, indicating those who will suffer the greatest impacts.20 This brings us to our urgent need to reimage the way in which we intervene in cities, especially in precariously and unplanned areas. The new infrastructure that will shape cities in the future will need to be able to deal with the effects of climate change on multiple levels.18

One of the principal effects of global warming is the increase in the intensity and frequency of heat waves. It is estimated that in 2050 more than 1.6 billion people, living in more than 970 cities, will face sustained extreme heat conditions above 35°C (95°F) for three consecutive months.19 Of these 1.6 billion people, 215 million will live in poverty, in over 230 cities.20 The impact of increased temperatures and heat waves in cities is aggravated by the urban heat island effect. This is a phenomenon in which cities tend to be warmer than their surrounding rural and suburban areas as a result of morphological characteristics such as the material properties of the urban landscape. This makes areas of urban centers more susceptible to extreme heat, which can worsen air quality, cause dehydration, heat stroke, cardiovascular complications, illnesses, kidney disease, and death.21 If no action is taken, the OECD calculates that in 20 years’ time, the tropospheric ozone will cause 30 premature deaths per day per million inhabitants.

Map 03 shows the temperature increase in the austral summer by 2100; the effects of global warming for cities is significant. Map 03 also highlights cities with average temperatures of greater than 33°C (91°F) during the austral summer, and their growth.

Rising temperatures also cause more frequent droughts and floods, which directly affect the most vulnerable portions of the global population. By the middle of the century, more than 650 million people in over 500 cities may face a minimum of 10% decrease in freshwater availability. This is worrying, considering that around 500 million people live in conditions of borderline water scarcity. Furthermore, another 2 billion people (which is almost one-third of the global population) live in countries with water supply problems.22

Floods are exacerbated due to extreme weather events such as heavy rains, hurricanes, and the gradual rise in sea level. The latter is another important effect of global warming, which especially affects coastal areas. Graph 01 shows historical trends over time in sea level increase, temperature changes, population growth, and the population affected by natural disasters, according to future predictions for 2100 that indicate high impacts for cities. Future predictions are based on a high emissions scenario (RCP 8.5), with a significant increase in temperature and sea level. The disaster rate increases to the point where countries could have to deal with up to six natural disasters at one time for the year 2100, with a population of 1.9 billion people.23
Every year, the global urban population grows an average of 67 million.

In Latin America and the Caribbean, the cities with the highest population growth in the region by 2014 will be Mexico City, São Paulo, and Buenos Aires. The first two will be ranked as 2 of the 10 most populated countries in the world.

Data source: UN Data 2018
MAP 03
PROJECTION FOR TEMPERATURE INCREASE BY 2100.

Data source:
CEDA (Centre for Environmental Data Analysis); the model used for climate prediction: HADGEM2 (Hadley Centre Global Environmental Model Version 2) with scenarios RCP 8.5.
Rising sea levels are a latent risk for urban areas. Between 1993 and 2003, both satellites and tide gauges recorded rises in sea level of approximately 3.2 mm per year. Many cities face further local increases in sea levels, faster than the world average, due to the subsidence caused by compaction of sediments and groundwater extraction. More than 90% of all urban areas are coastal, which puts most of the cities around the world at risk of flooding from rising sea levels and powerful storms. Urban centers built in low-lying deltas are especially vulnerable, as higher coastal storm surges will present a greater risk to life and property; these conditions are exacerbated by rising sea levels and higher waves, which will be able to go deeper into interior foundations of cities. The intrusion of saltwater, induced by rising sea levels both upstream and in the coastal aquifers, can put the urban water supply in great danger and contaminate agricultural land, which in turn increases risk of the underground waters to flood.

In 2050, over 1.6 billion people living in more than 870 cities will undergo extreme heat conditions as high as 35°C (95°F) for three consecutive months. Of these, 215 million people will be living under conditions of poverty in over 230 cities.


GRAPH 01
PROJECTIONS FOR THE INCREASE IN TEMPERATURE, RISE IN SEA LEVEL, FREQUENCY OF DISASTERS AND GLOBAL POPULATION, 2100.

6 natural disasters which countries may have to deal with simultaneously, in the year 2100.

Historical Chronology 1950-2013

- Rise in temperature
- Rise in sea level
- Population affected by natural disasters
- Global population

Data source:
As demonstrated in Map 04, the rising sea level that is estimated for the year 2100 in the high emissions scenario RCP 8.5 would affect many coastal cities. The color cyan shows the range between 0 and 2 meters. Major cities with over 1 million inhabitants are plotted on the graph, together with their demographic growth within this range. Therefore, it is estimated that these would also be affected by the rise in sea level. The sizes of the circles represent the affected population. It is estimated that 340 million people will be impacted by the rise in sea level in 2050, in the high-emissions scenario. This figure will increase to 630 million by 2100, according to the map, with almost 90 million inhabitants in South America and 12 million in Central America. Other sources indicate that in 2050, over 800 million people worldwide, in over 570 coastal cities, will be at risk of coastal flooding from at least 0.5 meters above sea level. Given the rise in sea level and increase in continental floods, global economic costs for cities could increase to $1 billion annually by the middle of the century.

The effects of climate change, as we will discuss further in the coming paragraphs, have an even greater impact on the most vulnerable areas of cities, finding themselves at highest risk and with the lowest amount of resources to confront disruptive events. The inhabitants of these areas are the most susceptible to being displaced in the cases of climatic disasters, and it is very probable that they will be relocated to other areas that are equally as vulnerable. In 2020, 42 million people were displaced for climatic reasons, which makes up 10% of the world’s migration. It is predicted that in 2050 this number will increase to 200 million, which would be 60% of migration. The International Organization for Migration (IOM)
Rise in sea level projected for the year 2100 in the high emissions scenario (RCP 8.5)

Data Source:
Every second, a new migrant is forced into displacement due to natural disasters or environmental crises.

defines three categories of climatic refugees. The first is due to conditions of climatic stress that provoke a temporary displacement; these include heavy rainfall, flooding, earthquakes, or any reversible climatic event. After a period of time, the inhabitants can return to their cities. The second is caused by damage that is man-made and permanent, forcing people to relocate to new settlements. These can be pollutant events, or extreme cases such as the Chernobyl disaster. Lastly, the third category is caused by the degradation of natural resources in devastated habitats, for example, large droughts. In this case, cross-border migration tends to rise. The climate crisis has intensified migration in each of these categories. Today, almost 26 million people have been displaced due to disasters. This means that a new migrant is forcibly displaced every second due to natural disasters or climate crises. Of these, 75% of displacements for climatic reasons occur in cities with large poverty indices, mainly in Africa, Asia, and Latin America. Furthermore, over 66% of deaths caused by natural disasters occur in poor cities with precarious habitats. In 1995, there were 25 million climate refugees, globally. In 2010, climatic degradation and the effects of climate change caused the number of migrants to duplicate in this category; this amount is expected to quadruple and rise to 200 million by 2050.

In November 2020, according to data from the International Organization for Migration, Category 4 hurricanes Eta and Lota left over 9.9 million people affected, internally displacing over half a million people in Guatemala, Honduras, and Nicaragua. Therefore, the migrant caravans to the United States are also expected to increase.
LATIN AMERICA AND THE CARIBBEAN: ENVIRONMENTAL IMPACT AND CLIMATIC VULNERABILITY

On a regional scale, Latin America and the Caribbean (LAC) are particularly vulnerable to the impacts of climate change. By 2050, it is predicted that the rise in sea level, in temperature, and in the rate of rainfall will translate into an annual cost of approximately 2% to 4% of the GDP\(^3\). However, the region also contributes to 12% of GHG emissions globally, which is driven by forest, agricultural, and extractive sectors.\(^3\) In per capita terms, LAC generates more greenhouse gas emissions than other developing countries, such as China or India.

To understand the scale of the climate challenge of each country, it is useful to understand the relative weight and reconstruct the chronology of the emissions in the region. For example, looking at CO2 emissions, we can see how Latin America represents a relatively small percentage of global CO2 emissions. However, both global and Latin American emissions follow the same global pattern of rapid increase up until the last five years, where it is shown to have stagnated and even slightly decreased. In Graph 02, we can see an information schedule that shows the history of CO2 emissions on a global level, in the LAC scale, Southern Cone, and Argentina. In each graph, the proportion of emissions are shown in different colors, according to the following scale: the Southern Cone, with 301M tons, contributes to 15%.

Graph 02
CO2 EMISSIONS - GLOBAL, LATIN AMERICAN AND THE CARIBBEAN, THE SOUTHERN CONE (ARGENTINA, CHILE, PARAGUAY, AND URUGUAY) AND ARGENTINA.

Latin America and the Caribbean (LAC) represents a small part of total global emissions, but the region, as well as the Southern Cone and Argentina, have continued the same global trend of rapid growth up until the last five years.

Comparing the GDP with the amount of GHG emitted by countries in the region, in many cases the relation is directly proportional and at the same time is inversely proportional to the affected population; presenting issues of equity, social justice, and rights to the city.


of Latin America’s total emissions, with 204M being emitted from Argentina. In the same way, Graph 05 (above left) shows the emissions in 2016, where we can note that emissions in the Southern Cone depend principally on Venezuela (5.50kt of CO2 per capita), Chile (4.71kt of CO2 per capita) and Argentina (4.62kt of CO2 per capita). These are the countries that emit the highest amount of CO2, followed by Guyana, Surinam, Ecuador, Brazil, Colombia, Uruguay, Bolivia, Peru, and Paraguay. Meanwhile in Graph 04 (above right), we can see a rise in disaggregated emissions over time and its evolution in each country. This graph organizes the emissions into temporal sections of five years.

Finally, Graph 06 (below), shows the principle sectors that are responsible for emissions, which are eventually disaggregated by section to the Southern Cone, as seen in Graph 06. This final graph shows greenhouse gas emissions per section of every country in the Southern Cone, according to the National Inventory of Greenhouse Gases (IN-GEI). Those same graphs consider emissions (+) as well as gas absorption (-) in the use of land and forestry. The graph to the left shows the net value of emissions in kt of GHG, and the graph on the right shows emissions per capita of GHG/habitant. It is also clear that Chile and Uruguay absorb notable quantities of emissions thanks to their forestry and forestry industries, which in the case of Uruguay results in a negative balance, with 1.21 tons of GHG absorption.

If we compare, for example, the GDP with the amount of GHG emissions of these countries, in many cases it is clear how the relation is directly proportional, and at the same time, inversely proportional to the affected population, which is manifested in issues of equity, social justice, and rights to the city. Graph 07 (to the left), compares the global rate of CO2 emissions with countries’ GDPS and the natural disasters (shown in total number of events), the population affected in each country (shown in the size of the circles), and the rate of mortality (shown in the intensity of color). The countries were selected according to those which emitted the most CO2 and which were the most affected by natural disasters. The general trend shows that the effects of the emissions are spread indiscriminately and affect every country in the world. The trend also shows that the GDP influences the share of emissions as well as the amount of people affected and mortality.
CO2 EMISSIONS PER CAPITA AND BY SECTOR, AND GREENHOUSE GASES (GHG) IN THE SOUTHERN CONE AND LATIN AMERICA AND THE CARIBBEAN

4+ metric tons per capita of CO2 are produced by Venezuela, Argentina and Chile

Graphs 03, 04, 05

CO2 EMISSIONS PER COUNTRY (2016, METRIC TONS PER CAPITA)

Data source:
World Bank, CO2 Emissions (metric tons per capita) CEPAL. La Economía del Cambio Climático en América Latina y el Caribe.


GHG EMISSION IN LATIN AMERICA AND THE CARIBBEAN PER SECTOR (2014)

46% Energy
23% Agriculture
19% Change in use of land and agriculture
06% Waste
04% Industrial processes
02% Boiler Fuel
**GRAPH 06**

GHG EMISSION IN THE SOUTHERN CONE BY SECTOR (2016)

**GHG EMISSIONS BY SECTOR**

(KT CO₂)

- **ARGENTINA**
  - Energy: 193,420 kt
  - Industrial Processes and use of products: 20,050 kt
  - Agriculture: 135,530 kt
  - Waste: 14,440 kt
  - Total: 364,440 kt

- **CHILE**
  - Energy: 11,801.6 kt
  - Industrial Processes and use of products: 6,805.6 kt
  - Agriculture: 769.8 kt
  - Waste: 1,98 t
  - Total: 18,587 kt

- **URUGUAY**
  - Energy: 6,805.6 kt
  - Industrial Processes and use of products: 531.8 kt
  - Agriculture: 11,801.6 kt
  - Waste: 0.32 t
  - Total: 18,861.6 kt

- **PARAGUAY**
  - Energy: 0.02 t
  - Industrial Processes and use of products: 0.02 t
  - Agriculture: 0.02 t
  - Waste: 0.19 t
  - Total: 0.24 t

**GHG EMISSIONS BY SECTOR**

(METRIC TONS PER CAPITA)

- **ARGENTINA**
  - Energy: 4.44 t
  - Industrial Processes and use of products: 0.46 t
  - Agriculture: 3.11 t
  - Waste: 0.35 t
  - Total: 8.36 t

- **CHILE**
  - Energy: 4.79 t
  - Industrial Processes and use of products: 0.14 t
  - Agriculture: 4.06 t
  - Waste: 0.32 t
  - Total: 9.05 t

- **URUGUAY**
  - Energy: 2.36 t
  - Industrial Processes and use of products: 0.19 t
  - Agriculture: 0.32 t
  - Waste: 0.19 t
  - Total: 2.54 t

- **PARAGUAY**
  - Energy: 0.92 t
  - Industrial Processes and use of products: 0.14 t
  - Agriculture: 4.06 t
  - Waste: 0.19 t
  - Total: 5.15 t

**Clarification:** Argentina does not make the distinction between agriculture and land use, change in land use, and silviculture as other countries do.

**Data Source:**
GRAPH 07
NATURAL DISASTERS, GDP, AND EMISSIONS (WORLD)

Data Source:
HealthData, http://ghdx.healthdata.org/gbd-results-tool

NATURAL DISASTERS AND GDP (LAC)

As well as developments in emission reduction on a city scale, the region is confronting great challenges in augmenting its resilience to new and changing scenarios. If, in general, we think of the impact of climate change in cities as a phenomenon of the future, 70% of cities are currently dealing with the effects of climate change. The financial effects of climate change could be as devastating as the physical effects. Furthermore, the unexpected disruptions of storms, floods, and droughts can provoke important disruptions to the city’s government as well as commercial operations. Given the rise in the recurrence of these phenomena, the capacity for fiscal reaction and uptake will also be reduced, which will in turn limit the capacity for resilience in those countries. This can be seen in Map 05, which displays disasters related to climate change that have been reported by Latin American cities with over 300,000 inhabitants. To the left is a description of the relation between the number of disasters and the magnitude of the impact. To the right, the cities that have been impacted by more common disasters are displayed, including: droughts, storms, and heat waves.

Natural disasters already imply important losses for countries in this region. Graph 08 shows the direct economic losses as a percentage of the GDP for Latin American countries, not taking into account whether they are or are not products of climate change. This allows us to see that certain years have especially affected an ample range of countries, for example, in 2010-2011. Due to climatic inequality, the direct costs of these changes will most likely be borne by the least favorable parts of cities, which are precisely for whom we should propose agile and effective solutions. To the right of this graph, there is a comparison between natural disasters (mortality and population affected) represented by the average over the last ten years, and the GDP of Latin American countries. The trend shows that the majority of the countries have been affected by (at least) one disaster per year in the last decade, and over 50% have had two or more natural disasters. Smaller countries with a low GDP are less equipped to face the aftermath of disasters. For example, Haiti suffered an average of four disasters per year with over 20,000 deaths, which is approximately 10 times more than any other country in Latin America.
CITIES IMPACTED BY THE MOST COMMON DISASTERS: DROUGHTS, STORMS, AND HEAT WAVES

Data source:

MAP 05
CITIES’ VULNERABILITY TO CLIMATE CHANGE
Number of disasters and magnitude of its impact on Latin American and Caribbean cities with over 300,000 inhabitants
**GRAPH 08**

NATURAL DISASTERS AND GDP (LAC)


*Data from Colombia are not included due to inconsistencies in the original database.*
Alterations in monsoon systems, unexpected rains, large droughts and a significant rise in the sea level could completely transform the landscape of coastal development across the globe, which would cause the displacement of entire settlements and cities.

In the same way, **Graph 09** relates the general conditions with respect to climate change and vulnerability to climate change, which depends on the socioeconomic factors defined in the previous map. With respect to climate change, Caribbean countries are in the lead (Trinidad and Tobago, Barbados, Bahamas, Guyana, Haiti, and Jamaica). However, with regard to vulnerability, only Haiti and Guyana are in the five most vulnerable countries, along with Cuba, Bolivia, and Paraguay. Another example is the case of Hurricane Mitch that in 1998 affected Belize, Honduras, Nicaragua, El Salvador, and Guatemala, causing 3 million injuries, which is 12% of the population. Due to the cities’ failure to react in the recuperation phase after the disaster, there is no certain data on the matter; however, it is clear that many families emigrated from their cities of origin, which was used as an adjustment strategy through pre-existing migration corridors.

For example, Argentina is among the 14 countries that are most affected by floods, arriving at losses of 1.1% of the National Gross Domestic Product. Long-term projections (which are always subject to incertitude) estimate that by the year 2100 the sea will have risen between 10 to 90 centimeters, and that global warming could oscillate between 1.4°C and 5.8°C. This could signify the displacement of whole cities and affect different islands around the globe, whose migration population would be absorbed by cities. These displacements will principally be due to the worsening consequences of global warming, which could generate alterations in monsoon systems, unexpected rains, large droughts, and a significant rise in the sea level. These will completely transform the landscape of coastal development across the globe.
The effects of climate change heavily impact the most vulnerable populations in the region and increase migratory flows, which are increasingly propelled for climatic reasons. Between 2000 and 2015, 8 million people in South America migrated for environmental reasons. The following maps demonstrate the impact of environmental crisis and climatic events on migratory flows. Map 06, for example, exposes displacements for environmental and geomorphologic reasons. The countries with the least amount of displacements do have more immigration (Belize, Panama, and Suriname). Cities with a large population are highlighted, such as Puebla, Guatemala City, Havana, Santo Domingo (which receives many migrants from Haiti), Curitiba, and Porto Alegre. In Argentina, the country with the highest number of regional immigrants, Buenos Aires, Rosario, and Córdoba are highlighted. In the same vein, Map 09 shows the change in land use, which is reflected in the map to the left of the graph. The statistics seen on the right show the NPP (Net Primary Productivity, the velocity at which trees store energy such as biomass, and absorb carbon). This variable follows only one indicative pattern in Belize, which has a high NPP and immigration. In the other extreme is Paraguay, whose very low NPP coincides with very high immigration.

Map 10 represents the risk of river flooding, which is scattered throughout the region, concentrating at the center of South America. Havana, Guatemala City, Lima, Guayaquil, Recife, and Salvador are highlighted as the largest cities which are at risk of flooding. Additionally, Map 12 represents the basic depletion of water, according to the relation between the total consumption of water and available renewable water supply. The total consumption of water includes domestic, industrial, irrigation, and expenditure uses. Available renewable water supplies include the impact of the users of upstream water (consumption) and large dams on the availability of downstream water. The significant decrease of water from the source is similar to hydrological stress from the source; however, in place of using the total extraction of water (consumptive as well as non-consumptive), the depletion of the baseline is calculated using only the consumptive extraction
Change in vegetation level

LOW DEFORESTATION

DOMINICAN REPUBLIC
IN: 3.5%  EM: 0.9%

REGIONAL IMMIGRATION AND EMIGRATION 2017
DIF: 2015

3.4

COSTA RICA
IN: 7.6%  EM: 0.6%

2.9

CURA
IN: 0.1%  EM: 0.7%

2.6

CHILE
IN: 2.0%  EM: 1.6%

2.0

HIGH DEFORESTATION

ECUADOR
IN: 1.6%  EM: 0.6%

-1.8

GUATEMALA
IN: 0.4%  EM: 0.6%

-1.7

PARAGUAY
IN: 8.1%  EM: 11.1%

-5.0

HONDURAS
IN: 0.3%  EM: 0.7%

-5.4

Data source: UN data SDG indicators, GIS map: World Resources Institute C-C-11-Deforestation.
Reduction of the Primary Net Production

**ECOLOGICAL DESIGN**

**IDB**

Data Source: MODIS Net Primary Production (NPP), GIS: FAO C-C-10-Land deterioration.

**HIGH NPP**

<table>
<thead>
<tr>
<th>Country</th>
<th>IN</th>
<th>EM</th>
<th>2019 NPP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uruguay</strong></td>
<td>1.8%</td>
<td>0.4%</td>
<td>102.9</td>
</tr>
<tr>
<td><strong>El Salvador</strong></td>
<td>0.8%</td>
<td>1.1%</td>
<td>100.3</td>
</tr>
<tr>
<td><strong>Trinidad and Tobago</strong></td>
<td>1.0%</td>
<td>0.7%</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Belize</strong></td>
<td>1.2%</td>
<td>1.5%</td>
<td>97.2</td>
</tr>
</tbody>
</table>

**LOW NPP**

<table>
<thead>
<tr>
<th>Country</th>
<th>IN</th>
<th>EM</th>
<th>2019 NPP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barbados</strong></td>
<td>2.4%</td>
<td>0.8%</td>
<td>84.7</td>
</tr>
<tr>
<td><strong>Argentina</strong></td>
<td>4.0%</td>
<td>0.7%</td>
<td>97.9</td>
</tr>
<tr>
<td><strong>Panama</strong></td>
<td>3.5%</td>
<td>0.8%</td>
<td>96.9</td>
</tr>
<tr>
<td><strong>Paraguay</strong></td>
<td>2.1%</td>
<td>1.1%</td>
<td>4.5</td>
</tr>
</tbody>
</table>
MAP 10
RIVER FLOODING

Risk of Flooding

Data source:
Aqueduct World Resources Institute C-C-13 Flooding.

Affected population

Data source:
Aqueduct World Resources Institute C-C-13 Flooding.
MAP 12
WATER DEPLETION

Level of basic water depletion

- 0.5-3.0
- 0.0-0.5
- 0.0-0.1
- <0.5

Affected population

<0.5, 0.5-1, 1-5, >5

Data source:
Aqueduct World Resources Institute C-C-14-Water Depletion.
Countries in the region have presented their determined contributions on a national level, or CDN, reflecting their goals to reduce emissions as a measure of adaptation to climate change. This will limit the rise in global temperatures to far lower than 2 degrees centigrade, on top of preindustrial levels. These efforts will continue, increasing the limit in the rise in temperature up to 1.5 degrees centigrade.

(WRI Aqueduct, 2019). The areas that currently consume more water in relation to its resources are the eastern Andes, southeastern and northeastern Argentina, and northern Mexico. Cities that are highlighted for their consumption of water in relation to their size and consumption are Mexico City, Monterrey, and Santiago. In the same line, Map 13 shows the base hydric stress, which measures the relation between the total extraction of water and renewable underground and superficial water supplies. Water extractions include domestic, industrial, and agricultural uses as well as breeders of consumption and non-consumption. The available renewable water supplies include the impact of the water users who consume upstream water and large dams on the availability of downstream water.

The highest values indicate more competition between the users (WRI Aqueduct, 2019). The areas that currently suffer a high hydric stress are the eastern Andes, southeastern Argentina, and northern Mexico and Venezuela (there is currently a large number of people emigrating from Venezuela).

In this context, it is important to note that the countries in these regions have presented their nationally determined contributions, or NDCs, reflecting their objectives to reduce emissions as a measure of adaptation to climate change. This will limit the rise in global temperatures to far lower than 2°C on top of preindustrial levels. These efforts will continue, increasing the limit in the rise in temperature to up to 1.5°C. However, these compromises should be integrated vertically in order to secure the maintenance of the targets on a subnational and local level. In order to allow for the planning and execution of mitigation and adaptation on an urban scale, we must take into account the territorialization of this process, changing the patterns of emission and making sure that the local context is taken into account when thinking of solutions of resilience. This is a key milestone in the increase of quality of life for the most marginalized neighborhoods that are vulnerable to climate change.
THE VULNERABLE CITY IN THE REGION: PRECARIOUS, UNPLANNED, AND INFORMAL SETTLEMENTS

The city is planned according to systems of fixed and permanent infrastructure, adapted to relatively stable climate conditions. Tram lines, motorways, electricity grids, and water networks allowed for the rapid expansion of cities and the accommodation of millions of new citizens. This led to large rural to urban migrations as a product of the Industrial Revolution. For example, at the beginning of the 1800s, the population in London was 1 million, and by 1950, the population of Greater London was 8 million. In Latin America and the Caribbean, the same process occurred in a very accelerated and far more sudden way.

Mexico City, for instance, grew from 3.1 million inhabitants in 1950 to 8.2 million by 1990. If we include the surrounding cities of Cuernavaca, Querétaro, Puebla, Cuahtla, and Pachuca, there is a megalopolis of 50 million inhabitants, which is almost 40% of the nation’s total population. The excessive growth of Mexico City occurred as a ‘centrifugal’ effect that began in the 1970s, when the Federal District presented minimal growth, while the periphery went through a process of accelerated urbanization. In this process of un-

Climatic inequality, amongst other issues, is a product of the accelerated growth in the region’s urban fabric. It also presents diverse degrees of resilience and capacities of effective response in the face of high climatic pressure.

52. Population Census Data in the United Kingdom.
The larger regional cities attract a greater segment of the population than is capable of being absorbed into the formal market, generating vast sectors of unplanned, precarious, and highly informal settlements.
In most cases, precariously built informal settlements on the outskirts of planned cities are the result of a major effort by countries that have been legalized, without improving their precarious conditions.

Although the percentage of population living in informal settlements has risen, this is the result of a major effort by countries to foresee solutions for living situations and remedy informal situations. Many programs of neighborhood improvement have introduced infrastructures, services, and property owners, which have generated great transformations in precarious neighborhoods, creating infrastructures, services, and property owners, which have generated great transformations in precarious neighborhoods. It also presents diverse degrees of resilience and capacity to respond to the climate crisis, when we consider that the data corresponds to the definition of informal settlements by the United Nations. Although the percentage of population living in informal settlements in Latin America and the Caribbean living in informal settlements has increased, the sum total of people residing in informal situations continues to decrease, the percentage of growth of informal neighborhoods has been decreasing, the sum total of people residing in informal situations has risen. This is the result of a major effort by countries to foresee solutions for living situations and to remedy informal situations.

This is the result of a major effort by countries that have been legalized, without improving their precarious conditions.

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According to the document on the subject of informal settlements, published by Habitat III (2016), informal settlements are defined as: “residential areas in which: 1) the inhabitants do not hold the right of land tenure or dwellings in which they live, under modalities ranging from illegal occupation of a home to informal rental; 2) the neighborhoods often lack basic urban infrastructure and services; and 3) the dwellings do not comply with building and planning regulations and are usually located in areas that are geographically and environmentally dangerous.” (Temas Hábitat III, 22 Asentamientos Informales, Quito 2016, 1). The definition is based on the following sources: UN-Habitat. (2003). The Challenge of Slums; UN-Habitat. (2013). The State of World Cities Report 2012/13.

Today, the level of climatic inequality mirrors the level of urban inequality, and therefore climate action presents a window of opportunity to close this gap in the most vulnerable cities. The level of climatic inequality today mirrors the level of urban inequality and, therefore, climatic action could present a window of opportunity to close the gaps in the most vulnerable cities. In a global context, the region is noted for containing cities that are highly unequal, whose populations represent over a quarter of their respective national population. Buenos Aires, Lima, Managua, Montevideo, Panama City, San Jose de Costa Rica, Santiago de Chile, and Santo Domingo illustrate this situation. As we can see in Map 14, it is estimated that Latin America and the Caribbean will continue to grow and that the cities that will lead the region in population growth by 2035 will be Mexico City, São Paulo, Buenos Aires, Rio de Janeiro, Lima, and Bogotá. The first two cities will globally rank as one of the ten countries with the highest population. We can foresee that this growth will be accompanied by a rise in the number of people residing in precarious areas, which means a high amount of people in situations that are vulnerable to the climate crisis; for these, we need to think of new and improved strategies of mitigation and territorial adaptation.

The book endeavors to create a sense of scale of the impacts of the climate crisis in the most vulnerable parts of our cities (the unplanned, spontaneous, and/or informal city), studying their characteristics and projections, but also exploring strategies and technologies that can help to create resilient surroundings out of the unplanned contexts that are resilient in the face of climatic pressures that will ensue in the coming decades.
Mexico City, São Paulo, Buenos Aires, Rio de Janeiro, Lima, and Bogotá will lead in population growth in the region in the year 2035. It is estimated that this growth will be accompanied by a rise in people residing in precarious areas. This means that a large quantity of people will be in situations that are vulnerable to climate change. It is for these people that we need to think of new and better strategies of territorial mitigation and adaptation.
2

FORMS OF VULNERABILITY IN THE FACE OF A TRANSFORMING CLIMATE

Along with the vulnerability to the effects of climate change discussed above, public health risks, the appearance of diseases linked to the degradation of ecosystems, and the transmission of pathogens from wildlife to humans, are increasingly frequent. In the 20th century, we had three pandemics, and in the 21st century, we went through the SARS epidemics in 2003, MERS in 2012, and now, COVID-19. The impacts of the latter have greatly affected our cities, exacerbated development problems and inequality, and, it is estimated, increased the number of people living in poverty in Latin America from 185 to 220 million. Dengue, which has supposedly been eradicated, reached more than 3 million cases in the Americas in 2019, the highest number of cases in history.

Health disasters (COVID-19 in particular) have forced us to think of a more sustainable way of living in the city and highlighted the importance of including public space and landscape infrastructure as key elements for urban resilience. Environmental vulnerability is chronically growing, exponentially increasing the level of risk for the region’s informal settlements. The question of how to address risks in the region’s settlements is crucial. Ecological design and nature-based solutions can offer great opportunities to help reduce different types of vulnerability, increase the resilience of slums, and also minimize the carbon footprint of cities. In this chapter, we will address the main issues at stake and the conditions for their implementation.
The dynamics of uncontrolled urban expansion affect and modify the trends of risk and compromise the capacity for response in the case of disasters. In terms of urban planning, there is a lack of codes for long-term zoning trends and construction, which could limit the possibilities of infrastructure adaptation and put lives and goods at risk. Vulnerability to climate change does not only depend on adverse climate conditions, but also on the capacity for society to anticipate, confront, resist, and recuperate from its impacts. This can be very complex in informal and precarious settlements. Informal settlements are partly the result of an illegal occupation or subdivision of lands that is not permitted. They are also caused by practices of exclusion that have historically contributed to conditions of economic inequality and unequal wealth distribution. Informal settlements are typically established by illegal entrepreneurs or new residents that occupy either public, communal, or private land, marking sites and constructing rudimentary housing. Generally, they do not have any public services such as street paving, lighting, water, and sewage systems. As time passes, constructions expand, provisional materials are replaced with other more durable ones, and public services start to appear. In the settlements’ first phases, ownership tends to be insecure, particularly in those that are located on public, communal, or private land that was illegally occupied by new residents. This delays the occupation’s legal recognition and can then impede the provision of services, the development of more urban infrastructure, and the general legality of the residence. Even when legal recognition is obtained, adequate services are not always provided, nor are environmental and hydroelectric conditions remedied in urban sites, which leaves the settlements in vulnerable and precarious conditions.
In an analysis on the vulnerability of informal settlements to climate change, David Satterthwaite, Diane Archer, et al., highlight how in the majority of cities in low- and middle-income nations there is often only partial and fragmented investment in infrastructure. Much of the time, informal settlements are ignored. Most urban infrastructure provisions (the water mains, sewage system, drainage systems, electricity grids, paved streets) would reduce risks, as would urban services such as hospitals, security, and maintenance of urban infrastructure. However, a partial investment can increase, change, or concentrate risks instead of reducing risk: the development of highways can accelerate storm run-off, while a larger, impermeable surface, if it is paved in reinforced concrete, can increase the air temperature. In the same way, the investments in river and superficial drainage in a city can increase the risks of downstream flooding. A focus on the reduction of risks, whether it is centered on immediate or root problems, challenges local governments, planners, and communities to work on a city scale. Integrated development of the infrastructure would also serve all urban inhabitants. Poor-quality infrastructure and lack of maintenance, which is characteristic of many low- and middle-income nations, are key determinants in the collapse of public hospitals, schools, bridges, and highways during extreme climate events. They also create difficulties in reactivating the infrastructure and services after disasters. There are complex problems of quality-control and responsibility for public works. An example is the lack of transparency in acquisitions, which is often conducive to corruption and low-quality work. Nations with low and middle incomes represent 85% of the global population that is exposed to earthquakes, tropical cyclones, floods, and droughts.


For the poorest groups, some impacts are direct; for example, floods can be more frequent and riskier. Others are less direct, such as the provision of local water or food reserves to a city, which can reduce availability for the most vulnerable communities, or cause a rise in prices and diminish supply access even further.
While cities grow, the demand and competition for limited clean-water resources will increase. Therefore, it is highly likely that climate impact will impact its availability and therefore increase pressure in urban areas across the world. Today, due to the growth in scarcity of local resources, cities often extract water from sources further away than the local ones. Therefore, in great part, urban water supply depends on the surrounding territories and on the exploitation of groundwater reserves, which extend the area that is potentially vulnerable to water shortages. In urban centers, critical services such as medical attention, food supply, transport, energy systems, schools, and retail business all depend on water supplies. Urban water supply deficits projected for the future will likely have a large impact on the availability as well as the price of water. The availability of water is often the first victim of the impacts of climate change. The decisions taken now will have an important influence on future industrial, domestic, and agricultural water supplies.

For the poorest groups, some impacts are direct; for example, they risk having more frequent floods. Others are less direct, such as the provision of local water or food reserves to a city, which can reduce availability for the most vulnerable communities, or cause a rise in price and diminish supply access even further. When considering the vulnerability of sectors with few resources, we should also consider how it will negatively affect their income (which can come from a variety of sources), as well as their base assets, the prices paid for their primary needs, their homes and infrastructure, and the services on which they depend.

For the inhabitants of informal settlements and especially for those with homeowners who don’t live in the area, the risk is even greater. Absent owners eliminate the link between those responsible for the quality of their houses and those at risk. Owners generally operate without regulations to comply with health and security norms. The combination of relatively high levels of risk exposure (threats, exposure, and vulnerability) together with a low institutional capacity to respond and recover, is reflected in the fact that over 95% of deaths caused by disasters in recent decades have occurred in the cities of low- and middle-income countries.

The Sixth Report of the International Panel on Climate Change (IPCC) defines risk as “the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems.” Risks of natural disasters and the consequences of climate change result in the interaction of three elements: climate-related hazards, exposure, and vulnerability. Hazards refer to facts or physical tendencies that can cause negative impacts on people and their surroundings, such as rising sea levels, floods, droughts, or heat waves. Exposure refers to the presence of people and settlements in places that could be negatively affected. Vulnerability refers to the susceptibility of suffering injuries as a product of circumstantial dangers that are due to physical, social, economic, or environmental factors. If vulnerability decreases, it is also because the capacity to respond and adapt to pressure increases.

Not only is exposure to dangerous events higher in informal neighborhoods, but the effect is also more intense or is reflected in more serious impacts in these zones. For example, changes in the increase in maximum temperature for more days per year are more likely to happen in informal neighborhoods, due to the lack of vegetation. Also, the impacts are accentuated by the low quality of the housing, which has inferior isolation and ventilation systems. Floods and landslides, due to more intense precipitation, occur with greater frequency in unplanned neighborhoods situated near rivers, gorges, or slopes. The houses and other possessions in these neighborhoods are rarely insured, and the damage can compromise indispensable income for sustaining the affected families. Some of the more complex effects of climate change, such...
Changes such as the increase in maximum temperature for more days per year are more likely to happen in informal neighborhoods, due to the lack of vegetation.

as droughts or the increased frequency of tropical cyclones, compromise access to food and water for the poorest groups in society, which in many cases coincide with the inhabitants of informal neighborhoods. Many residents of informal settlements depend on services and informal employment, which would not be guaranteed if access to the workplace is interrupted by critical events. The rise in sea level can affect communities that are closest to the coast, or can reduce land availability in urban centers and diminish its perceived value. This could potentially create new displacements or social marginalization.

The direct relation is that the higher vulnerability, exposure, and intensity of the event, the higher the risk. This analysis focuses on associated risks for vulnerable communities living in informal settlements. The impact of meteorological phenomena and their treatment as risks depend on the quality of housing, its location in the territory, ecosystem services on which they depend, and other variables of the urbanization process and its economic development. This determines the way that the city and its inhabitants are affected.

Understanding vulnerability and risk in informal settlements implies a consideration of how the effects of climate change not only increase ecological pressures, but also increase the obstacles for poverty traps and of breaking cycles of intergenerational precarity. In this way, it’s useful to consider stressful elements that link climate change to vulnerable neighborhoods, in particular its capacity to create friction or scarcity. In order to define the risk of a territory from a physical and ecological standpoint, it is important to consider the risk of climate change impacting biological (sanitation, food security), economic (low income, unemployment, lack of service access), social (violence, gender, cohesion, community organization), and cultural dimensions (migration, ethnic exclusion), among others. Poverty multiplies exposure and increases diverse vulnerabilities. This, as well as geological and climatic risks, imply a great challenge when developing tools to reduce multidimensional vulnerability, attacking multiple aspects simultaneously.

Territorial vulnerability is understood as the convergence of interacting factors and characteristics of risk. It is important to note that territorially, precarious or informal settlements are not isolated systems that are separate from formal cities. We must not consider the
exposed risks of the inhabitants as a purely environmental issue. The factors that increase risk are indeed environmental in nature, but they are also social, economic, and cultural; these dimensions are mutually connected and determinate. Informal settlements function as complex socioeconomic, interdependent, and integrated systems. An ecological focus can allow us to understand urban fragments as dynamic spaces, as it pre-establishes each system’s flexibility in the face of anthropogenic or climate disruptions, adapting for the protection of life and goods, as well as maintaining functional continuity.

The principal and most studied aspect of territorial risk is ecological (or physical), territorial vulnerability, that is, the vulnerability of a territory in relation to its ecosystem location. This primordial dimension can be considered the first source of territorial stress that eventually triggers an increase in barriers to social and urban neighborhood integration. It is very sensitive to ecosystemic pressure produced by climate change. Due to the interdependence of the conditions of vulnerability, it is difficult to achieve their conceptual separation. However, it is useful to do this in order to advance through levels of specificity toward more effective interventions. The location of a neighborhood, as well as the distribution and quality of its buildings, can affect conditions of vulnerability, exacerbate risks, and increase the impact of disasters. For example, land and building distribution can modify the local microclimate and intensify existing risks when there is an increase in temperature, wind circulation, turbulence, and limit of water permeability. The expansion of vulnerable building areas that are at risk of landslides, floods, and contamination puts a larger portion of the community at risk. Additionally, there are other factors that can multiply risks, such as the proximity of different land uses (for example, residential areas that are close to transport routes, other infrastructures or industrial areas); the use of inadequate construction materials and techniques; the unfavorable orientation of structures in space; and a lack of infrastructure for waste, wastewater, and rainwater elimination. The informal settlements’ residents are not as capable of responding, replacing, and restoring occasional losses for themselves, which increases their degree of vulnerability.


27. C40 Cities and UCCRN. (2018), 32.

In order to define the risk of a territory from a physical and ecological standpoint, it is important to consider the risk of climate change and its impact on biological, economic, social, and cultural dimensions. Poverty multiplies exposure and increases the diverse vulnerabilities.
and particularly affect women, who are more exposed to informal labor (54.3% women – 52.3% men). At the same time, the youth population accounts for higher rates of informality than adults (46.2% and 40.4%, respectively). The relationship between education levels shows that informality decreases when education increases. There is also a clear relationship between informal labor and poverty. The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems.

For decades, informal labor has constituted one of the most persistent and important challenges within Latin American economies, since it negatively affects people’s well-being and limits inclusive development. This is the case as long as informal work remains volatile, subject to exploitation, and without any guarantees or recognized rights. Economic informality is one of the characteristic factors in the region, which has a high heterogeneity of incidence between countries: less than 30% in Chile or Uruguay; and over 70% in Bolivia, Honduras, Nicaragua, or Peru. Crises such as COVID-19 can increase pre-existing structural weaknesses. The University of Oxford estimates that, because of the pandemic, advancements in reducing levels of multidimensional poverty could regress by eight to ten years. 98.2% of the 1.3 billion people who live in conditions of multidimensional poverty face risks of contaminated air, unhealthy water, and malnutrition. It is estimated that throughout the pandemic, global malnutrition has regressed three to six years in its advancement. Informal employment frequently continues to be the only form of subsistence for unqualified workers who are excluded from the formal sector. This exposes them to low social protection and higher income volatility, which altogether forms a highly vulnerable economic group. There is often a lot of rotation between different precarious jobs, which exposes people to greater vulnerability to effects of individual, domestic, or macroeconomic crises, such as those generated by COVID-19. According to the Food and Agriculture Organization of the United Nations, 1.2 billion people who live in precarious settlements are considered high risk in the context of COVID-19. These form what is called “the social vulnerability trap.”

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36. Bonnet, F. et al. (2018), 68.
37. The organization Women in Informal Employment: Globalizing and Organizing (WIEGO), for example, is a global network whose work focuses on empowering the working poor in the informal sector. Recognizing the magnitude of the phenomenon and some advantages that continue to justify and encourage informal work, the organization focuses on building a network, offering legal support and knowledge, expanding opportunities, and guaranteeing basic rights for workers. Website: https://www.wiego.org/about-us.
38. OECD. (2020).
39. OPHI and UNDP. (2020).
40. OPHI. (2020).
41. OPHI and UNDP. (2020).
42. OECD. (2020).
43. FAO. (2020).
44. OECD. (2020).
In order to explore the constraints of social territorial vulnerability, it is important to consider aspects such as gender inequality, the age of the community living in informal settlements, and the specific social characteristics of these groups. For example, climate pressures can have effects on gender gaps, by increasing the demands of citizens in the neighborhoods, due to a constant increase in illnesses or temporary interruption of access to services. The economy of precaution has a key role in enabling social and economic integration in low-income neighborhoods and cities in general. In order to sustain their daily lives, people with a certain level of dependence are in need of care by other providers. Given that this dependence is mainly managed in families, the presence of small children, disabled people, or elderly people with restrained autonomy increases the quality of resources that they need in order to survive. The spare time required by families for care puts pressure on their available time that is used for generating income. This situation particularly affects women, as they tend to assume primary responsibility of care for those who need it. A rise in events that increase the need for care can result in people’s incapacity to designate time to different economic activities and, with this, an increase in the gap in social and economic inequality.

The feminization of poverty has diverse edges; however, in informal settlements, it is principally based on three factors: informal employment, unpaid use of time, and precariousness in paid domestic work. Firstly, in LAC, 54% of women are informally employed and these values have increased for residents from informal settlements. In Argentina, for example, according to the latest data, the rate of women’s informal work (36%) is 2 percent higher than the rate for men, and women suffer the highest levels of unemployment and precarious labor. On average, women make 29% less than their male partners. This gap is wider for informal employees, arriving at 35.6%. In relation to the second point, women in Argentina dedicate three times more time than men to domestic work and unpaid care, according to an investigation on Unpaid Work and Use of Time by the National Institute for Statistics and Census (Instituto Nacional de Estadística y Censos, INDEC). In this way, according to the OIT, approximately 80% of single-parent

Climate pressures can have effects, for example, on gender gaps. The feminization of poverty has different aspects, but in informal settlements it is based mainly on three factors: informal employment, use of unpaid time, and precariousness in paid domestic work.

homes are headed by a woman (taking into account financial as well as care responsibilities), which is 3.2 times more time than men dedicate to this work. Taking a look at the gender gap and its relation to people’s neighborhoods in Argentina, women in informal settlements earn 9% less per hour than their male partners, and 47% less than women who live in neighborhoods with adequate infrastructure. The gap between neighborhoods for men is 10% less.

One of the most vivid expressions of the current crisis of care, which has seen an increase because of climate change conditions, is the infantilization of poverty. Half the children up to five years old live in families that do not have the minimum income needed to provide good quality care, creating a vicious cycle of poverty.

Precarious situations in informal settlements tend to be associated with violent situations. For informal workers, work-related violence can come from agents of the state: municipal police, transport agents, border police, etc., such as evicted people who suffer street peddlers in their places of work (on the street and market). In the case of home-workers (of which the majority are women), perpetrators of violence include members of the family (and employers’ friends or family), land-owners, employment-agency workers, and intermediaries. In the case of gender violence, determinant factors are lack of street-lighting and public-space lighting in places such as transport stations. Extreme climatic events can exacerbate precarious conditions for infrastructures and public services, compromising their functions and thus reducing even further the possibility of mitigating these risks.

Another aspect of social territorial vulnerability is access to education and its potential for generating income. The opportunity of having uninterrupted education can be impaired by the rise in climate events and the infrastructure’s inability to provide necessary shelter and comfort for the proper development of educational activities. This impacts the possibility of ensuring a better future. The volume of income accessed by families is conditioned by the educational capital they have accumulated. Effectively, a worker who has not completed secondary education receives 47.7% less income per hour than a worker who has. In informal settlements, 69% of working hours come from workers who did not complete secondary education. In neighborhoods with inadequate infrastructure, this proportion is less than 35%.

Among the difficulties for residents of informal settlements is the lack of access to public services and transport systems. This amounts to an expenditure in necessary resources, for example, time to access better work opportunities, and a larger domestic burden (such as having to make a long journey to access drinkable water). Situations like these and others of a social nature increase the poverty trap in neighborhoods and is also linked to the increase in the burdens of care, barriers in accessing the job market, and school desertion. Moreover, the lack of safe, high-quality public spaces, as well as overpopulation, makes it so that situations of confinement caused by climate or health crises can result in an increase in domestic violence. Investigations on the localization of work in cities in Brazil have proven that for the favela residents in Rio de Janeiro and São Paulo, there is a significant percentage who work in the favela itself, concentrating informal service and commercial activities. Notwithstanding the advantages that a nearby job offers, such as the possibility of taking care of family and the reduction of commute time and transport expenditures, the problem arises in cases of disaster, which not only affects their homes but also their places of work and therefore their sources of income. This is another example that when employment is informal, it is not guaranteed.

Lastly, there are cultural elements of territorial vulnerability, related to the gap in equality felt by social groups such as ethnic minority groups or migrants. Migrant women are a community that is particularly exposed to...
Migrant women are particularly exposed to the deprivation of rights, especially concerning sexual exploitation.
According to UN-Habitat, in Latin America, 1 in 4 people who live in urban areas today live in informal spaces, with all the inequalities this presents in access to basic homes, services, and opportunities. This situation shows that there is still a lot of space in situ to continue programs of neighborhood improvement and presents opportunities to improve mechanisms of intervention and make them more effective. This is seen in the definition used by the Organization for Economic Cooperation and Development (OECD), describing areas where groups live together on land whose owners have no legal claim or “illegally occupy” it. Other examples are unplanned settlements and areas where the home doesn’t comply with planning and construction regulations (unauthorized homes). These are mainly focused on the physical configuration and ownership of the land, without necessarily addressing the economic, social, and health dimensions of the informal city. Thinking of climate change and informal settlements necessarily implies a more complex understanding of the informal city and a more direct questioning of the various dimensions of vulnerability that ecological pressures generate for their inhabitants.
Informality provokes very high costs for its residents (like in precarious tenancies) along with lacks in public services, while discriminating against parts of the community and provoking environmental, health, and civil dangers of inequality. The limited access to public services and transport infrastructures is seen in the reduction of work opportunities and social development. This situation exacerbates the cultural stigma associated with informal communities, which often excludes inhabitants from the formal job market and makes nearby communities even more segregated (for example, through walls built along the perimeter). The general living conditions in these settlements do not comply with the minimum of urban norms: narrow roads, dense occupation, precarious construction, difficult access and circulation, lack of ventilation, lack of a sewage system and of public spaces. In many cities, informal occupation occurs in areas near water reservoirs susceptible to flooding, or protected forests.

Informality also generates immediate high costs of remediation for local governments or nations, which need to adopt improvement programs. It also generates a substantial quantity of indirect costs, which arise from the impact of informality in the field of public health, criminal violence, and other associated social problems that could be prevented by better access to opportunities. The supply of informal services, such as water, for example, is much more expensive than the formal supply. In Bogotá, it was calculated that the cost of the regularization of informal settlements is 2.8 times greater than the cost of developing urban lands with public services for poor residents. In the case of Monte Olivos, Guatemala, the price of water provided through tank trucks is 7 times higher than that which arrives through pipelines. The actual situation reflects what has come to be named “structural incapacity of public administrations in Latin American countries, especially at a local level, to guarantee sufficient economic lands and public services and/or housing unities in urban areas”. The predominant urban legal order in the majority of Latin American cities
has contributed to the establishment of some comparatively high land and property prices in both the formal and informal markets. This has propagated a pattern of socio-spatial segregation. The usual urban planning in major Latin American cities has reinforced informal processes and an absence of systemic public investments and service provision in zones of poverty.65

The above costs are calculated presuming that environmental remediation is possible, and whether the conditions of informal settlements allow for interventions that repair inadequate conditions and that mitigate existing risks in an acceptable way. When remediation is not possible, families living in vulnerable settlements may be relocated, with all the economic costs that this implies, not only for those who cover the value of the interventions, but also for families when they are separated from job opportunities and their support systems.

The effects of climate change in cities mean that the number of settlements that are not remedi able will progressively become higher or that risks increase, and therefore interventions will be more expensive and complex. Informal settlements are often not included in territorial plans and risk analysis. However, building a risk atlas for informal settlements would allow their fundamental vulnerabilities to be defined and their progress to be monitored. This would make the prioritization and formalization of available resources more effective, and improve the outcome of territorial interventions.

As a pilot experience, we have developed a first draft of a risk atlas for informal settlements, which generates a method that can easily be realized and replicated in different contexts. In order to evaluate vulnerability, the risk atlas begins by analyzing the density of informal neighborhoods and families, overlapping it with other risks: flooding, drought, land erosion, landscape fragmentation (understood as deforestation and loss of bodies of water), and suburban uses. Environmental and geological risks are two factors that increase vulnerability associated with poverty and the social exclusion of informal settlements. Moreover, risk levels have increased in recent decades, as territories with high levels of exposure have been increasingly occupied. These will continue to rise

65. Fernandes, E. (2011). In Brazil, for example, even after the recent launch of a far-reaching national housing program, there is very little formal housing available for low-income families (those living on less than three Brazilian minimum wages). Chile is one of the few countries in the region that has implemented a large-scale social interest housing policy, but it has not been exempt from criticism for having concentrated construction of low-income housing in remote peripheral areas, increasing socio-spatial segregation.

The effects of climate change are progressively increasing the number of precarious settlements that can no longer be remediated or, when interventions are still possible, they are more expensive and more complex.
due to the impacts of climate change. A fundamental aspect of the methodology is the elaboration of a Multidimensional Atlas. The climate crisis is a systemic problem, and the interconnection of different scales should be considered: “from the home to the basin”.66 These dimensions are fundamental for making decisions to frame localized interventions and, at the same time, for understanding its consequences, connections, impacts, and the gradual transformation of the framework in which they are found.

The objective of the atlas is also to understand the potential of green infrastructure to remedy conditions of territorial vulnerability. Vulnerability can be evaluated cartographically, generating a map that makes it possible to visualize different risks and to individualize areas that can benefit from the implementation of green infrastructure.

The case of Argentina

The first country for which we have developed the Risk Atlas of Informal Settlements is Argentina, where recently there have been nationwide surveys on the conditions of communities living in informal situations. In 2016, the government of Argentina promoted surveys of precarious housing and settlements, by establishing a National Register of Informal Settlements also known as ReNaBaP (Registro Nacional de Barrios Populares), the first official survey that mapped and characterized informal settlements in the country.67 This allows us to have a clear idea of the amount of people living in situations of extreme vulnerability. In accordance with the adopted definition, an informal settlement, barrrio popular, is that which unites at least eight grouped or adjacent families, half of whom do not have legal land rights, nor do they have regular access to at least two basic services (running water networks, electric energy networks with a home measuring system, and a sewage system).68 As seen in Graph 10, Argentina is aligned with Latin America in the percentage increase of urban population between 1990 and 2014. The residential community of informal settlements continued to increase in Argentina until around the year 2000, when it began to descend. However, over 1 in every 6 inhabitants in Argentina and every 5 inhabitants in Latin America and the Caribbean still live in informal settlements.69 As seen in Graph 11 to the right, more than 100,000 new families have been registered as residents of informal settlements each decade (132,526 new families in 2000, 197,591 in 2010, 104,589 in 2018). This proves how the phenomenon is constantly evolving.70 In 2018, the ReNaBaP identified that in 4,416 settlements (where approximately 935,000 families live), around 4,000,000 inhabitants live in vulnerable conditions.71 The majority of informal settlements and families are found in Buenos Aires (Graph 14, left), with 484,045 families living in 1,726 neighborhoods.72

In Argentina, 55% of informal neighborhoods are registered and have been settled before the year 2000, while 26% appeared throughout 2000–2010, and 19% between 2010 and 2016. Most often, these urbanizations have been developed in marginal areas, on residual contaminated lands that are exposed to flooding and heat waves, which have intensified in recent years as a consequence of climate change.73 It is estimated that 93.81% of homes do not have access to formal running-water systems, while 98.81% don’t have access to formal sewage systems, and 70.69% to formal electricity. At the same time, a lack of public spaces and recreational areas has been registered, which makes social cohesion more difficult and limits development. Approximately 45% of informal settlements are found in zones that are subject to some type of environmental risk.74 This trend of territorial occupation increases pressure on factors that worsen the effects of flooding and population vulnerability. Additionally, basic services in these neighborhoods have higher exposure, risk, and vulnerability to storm and heat waves, among other phenomena.75

67. Decree 358/2017 constitutes the formal recognition of the informal neighborhoods in Argentina.
69. Source: ReNaBaP (2018). The data indicates the number of new families per decade, not the total to date. It should be noted that the surveys of low-income neighborhoods of ReNaBaP are by family, and the data of UN-Habitat (2014), occupied in infographic 13, are by residents. The definition of “informal neighborhood” (UN-Habitat, 2014) and “low-income neighborhood” (ReNaBaP, 2018) do not exactly coincide either: An informal neighborhood is defined as a residential area in which: 1) the inhabitants do not have tenure rights over the land or houses in which they live, under the modalities that go from the illegal occupation of a house, to the informal rent; 2) neighborhoods often lack basic services and urban infrastructure; and 3) homes may not comply with building and planning regulations and are often geographically and environmentally located in hazardous areas (UN-Habitat, 2014). A low-income neighborhood is one that brings together at least eight grouped or contiguous families, where more than half of the population is not entitled to the land, nor regular access to, at least two out of three of the basic services (running water network, electricity network with home meter and/or sewage network) (ReNaBaP, 2018).
71. See the Law 25,170 (1993) and what it establishes through its changes.
73. Urban expansion has been characterized by informal settlements in low-lying and flood-prone areas, data collected in the National Survey on Social Structure (ENES), 2015. http://pnes.inegi.gob.mx/rapid.php. The information was estimated based on data from the SUMAR plan – Argentine public policy that promotes equitable access and quality health services for the entire population that does not have formal health coverage – for the population of the areas included in the representative sample of projects. https://www.argentina.gob.ar/health/sumar
74. ENES data, 2015.
75. From 1960 to 2010, an increase in the average temperature was observed in most of the country. ENES data, 2015.
Data source:

Ministry of Health and Social Development of Argentina (2019), Final Report: INTEGRACIÓN SOCIOURBANA DE BARRIOS POPULARES, Renabap data as of December 31, 2016: 935,000
families, around 4 million people – out of a total of 44 million inhabitants in Argentina, or 11%.


Percentage of population in informal settlements in LAC and Argentina
GRAPH 11
HISTORIC INFORMALITY IN ARGENTINA

Quantity of families in informal settlements

Data source: ReHabAll (2010), 2018 National Survey of Popular Neighborhoods. Clarification: the year 2010, when the data was taken, is used. Neighborhoods whose information is missing are not included. The measurement methods in this graph are different from the previous one. Therefore, the results show different trajectories.

Rise in quantity of families in informal settlements per decade

Families in informal settlements per decade

Total: 9,568, 5,712, 3,310, 12,866, 36,157, 46,070, 89,024, 86,283, 142,374, 132,526, 197,591, 104,589

Graph 12 shows the results of the 2016 ReNaBaP survey on the provision and quality of infrastructure in informal settlements. This affects resilience in the face of climate change. The data that is developed from a sample of studied territories, which includes Alto Valle de Rio Negro, AMR, Buenos Aires, CABA, Córdoba, Gran Corrientes, Gran Resistencia, San Miguel de Tucuman, Misiones, Neuquén, and Salta. A high percentage of the settlements, around 70%, have no sewage systems, sidewalks, or paved roads. This influences risks of flooding (almost 65%) and sustainable mobility. There is a lack of waste collection by municipalities and waste elimination by burning, almost 40%, which impacts environmental contamination, especially in the case of flooding. Other methods of reported waste collection include throwing garbage outside the neighborhood, into open-air bins and riverbanks or streams, which is damaging for health and the environment. Almost 84% of informal settlements in Argentina lack public sewage systems. All these factors influence the health and well-being of communities, which is key for their socioeconomic resilience in the case of extreme climate events.76


Only 24% of informal settlements in Argentina have squares or parks. Approximately 45% of these settlements are located in areas with some type of environmental risk.
Graph 12: Infrastructure in Informal Settlements in Argentina


MAP 15
SUMMARY OF RISKS OF INFORMAL SETTLEMENTS IN ARGENTINA BY PROVINCE

Number of families at risk by province

Data source:
SUMMARY OF INFORMAL SETTLEMENT RISKS IN ARGENTINA BY PROVINCE

Percentage of families at risk by province

Data source:
In the first instance, the Risk Atlas for Argentina is focused on exploring ecological territorial vulnerability and will later be expanded to the other dimensions of vulnerability. The Atlas works in a multidimensional manner, in order to arrive at a neighborhood scale in the city of Corrientes. To construct the Atlas, climate-change data from different sources is matched with information on informal settlements gathered by the National Register of Informal Settlements. The ReNaBaP collects and details information on slums and precarious settlements in Argentina and is published on the TECHO Argentina web page.\(^79\) Information from the Aqueduct page is also used in the hydrologic Risk Atlas from the World Resources Institute, with respect to climate change and the effects it produces, including flooding and droughts.\(^80\) For the maps related to types of land use, available information from the IDESA web page is used (Land Coverage of the Republic of Argentina), IGNA (Protected Areas), APN (Argentinian Ecoregions), SAYDS (Monitoring the Surface of Native Forest) and Global Surface Water (Lost permanent water transition).\(^81\)

This combined information recognizes previously realized efforts, such as the case of the System of Climate Change Risk Maps of the Environment and Sustainable Development Secretary, from the government of Argentina.\(^82\) Starting from this, the Atlas intends to explore the effects and impacts of climate change in informal settlements in particular.

\(^79\) The information is downloaded from the datasets available on the TECHO Argentina website: http://datos.techo.org/cd/IL/dataset/argentina-relevamiento-nacional-de-barrios-popular-2018. ReNaBaP website: https://www.argentina.gob.ar/habitat/renabap


\(^82\) Secretariat of Environment and Sustainable Development. Sistema de mapas de riesgo del cambio climático: https://simevac.environment.gob.ar/
MAP 17
INFORMAL SETTLEMENTS IN ARGENTINA
Argentina Scale

Data source:

BUENOS AIRES | N. of families: 484,045 | N. of settlements: 1,726
CABA | N. of families: 73,673 | N. of settlements: 57
SANTA FE | N. of families: 72,552 | N. of settlements: 341
MISIONES | N. of families: 41,181 | N. of settlements: 268
TUCUMÁN | N. of families: 34,847 | N. of settlements: 203
CHACO | N. of families: 32,570 | N. of settlements: 263
CÓRDOBA | N. of families: 23,030 | N. of settlements: 194
SALTA | N. of families: 20,195 | N. of settlements: 154
RÍO NEGRO | N. of families: 18,779 | N. of settlements: 152
ENTRE RÍOS | N. of families: 18,010 | N. of settlements: 169
CORRIENTES | N. of families: 17,956 | N. of settlements: 120

MENDOZA | N. of families: 16,585 | N. of settlements: 247
SANTIAGO DEL ESTERO | N. of families: 11,295 | N. of settlements: 52
JUJUY | N. of families: 10,577 | N. of settlements: 92
NEUQUÉN | N. of families: 10,546 | N. of settlements: 85
CHUBUT | N. of families: 5,977 | N. of settlements: 56
TIERRA DEL FUEGO | N. of families: 4,364 | N. of settlements: 36
CATAMARCA | N. of families: 5,225 | N. of settlements: 32
SAN LUIS | N. of families: 3,027 | N. of settlements: 23
SAN JUAN | N. of families: 2,858 | N. of settlements: 36
SANTA CRUZ | N. of families: 1,068 | N. of settlements: 6
LA RIOJA | N. of families: 421 | N. of settlements: 14
LA PAMPA | N. of families: 234 | N. of settlements: 4
MAP 18
INFORMAL SETTLEMENTS IN ARGENTINA
Mesopotamia bioregional scale

Data source:
MAP 19
ATLAS OF INFORMAL SETTLEMENTS IN ARGENTINA
Scale of Corrientes Province

Data source:
Quantity of families in informal settlements

+800

0-200

MAP 20
ATLAS OF INFORMAL SETTLEMENTS IN ARGENTINA
Scale of Gran Corrientes

Data source:
ReNaBaP (2018), Relevamiento Nacional de Barrios Populares 2016 - 10N (2019), Boundary lines.
In relation to land use, Map 21 analyzes important environmental risks. For example, intense cultivation can provoke land erosion and increase the risk of floods. Its transformation over time impacts the exposure of informal settlements to climatic, temporary, and permanent crises. The highest percentages of informal settlements in suburban areas are in the regions of Cuyo, Sierras Pampeana, and Noroeste, and also in the south of Patagonia. In these regions, there is a prevalence of forest and bush land use. However, at the national scale, the majority of informal settlements are situated on cultivated land. Graph 13 highlights the number of families living in suburban areas (left) and details the land uses (right). In Buenos Aires, for example, 138,243 families live in suburban areas, 63% of which are cultivated land. In San Juan, 100% of families in suburban zones are found on cultivated land. In Santa Cruz, 100% are found in pastures. In Chubut, the Pampa, La Rioja, and Neuquen, a high percentage are found in bush zones; in Salta and Corrientes, in forest zones; in Formosa and Catamarca, in wetlands. A small percentage of families in Buenos Aires are situated in dunes, affecting the areas’ resilience to coastal floods.

As shown in Map 22, in the provinces of Misiones and Entre Ríos, which are part of the region of Mesopotamia, cultivated land use prevails. In the Province of Corrientes, there are more pastures, together with wetlands and aquatic vegetation. In all three, the forest areas are mixed with the previous ones. These maps show the distribution of informal settlements in relation to the predominant uses of the region. Those that are found in or near bodies of water can be exposed to floods, due to seasonal variations. Those located in zones of forests are impacted by the consequences of deforestation, such as loss of habitats and soil erosion. Those in cultivated areas can suffer soil erosion and contamination from fertilizers.

In Argentina, the highest density of informal settlements can be found in rural areas. Settlements that are located near bodies of water may be exposed to flooding, due to seasonal variations. Those located in zones of forests are impacted by the consequences of deforestation, such as loss of habitats and soil erosion. Those in cultivated areas can suffer soil erosion and pesticide contamination from fertilizers.

**MAP 21**

**ATLAS OF INFORMAL SETTLEMENTS ACCORDING TO LAND USE**

Scale of Argentina

**Percentage of informal settlements in suburban areas by province**

*For this scale, segregation was done only for the ten departments with highest amount of suburban informal settlements.*

**Data source:**

GRAPH 13
SUMMARY OF RISKS BY LAND USE FOR THE PROVINCE

These graphs show the number of families in suburban areas (left) and show percentages of land uses in suburban areas. It highlights the number of families in suburban areas in Buenos Aires, whose resilience depends on the protection from coastal floods.
MAP 22
ATLAS OF INFORMAL SETTLEMENTS ACCORDING TO LAND USE
Scale of Bioregional Mesopotamia

Percentage of informal settlements in suburban areas by province

Land use
- Crops
- Forests
- Bush
- Pastures
- Bodies of water
- Flooded vegetation
- Dunes

PARANÁ
Families: 3,318
37% 63%

CONCORDIA
Families: 1,170
87% 13%

CONCEPCIÓN
Families: 3,223
94% 6%

CORRIENTES
Families: 1,011
100%

MISIONES, POSADAS
Families: 2,092
51% 49%

LEANDRO N. ALEM
Families: 1,379
54% 46%

IGUAZÚ
Families: 3,119
90% 10%

GRAL. M. BELGRANO
Families: 4,820
90% 10%

EL DORADO
Families: 2,046
100%

GUARANÍ
Families: 1,011
100%

Total amount of families in suburban informal settlements by department

*For this scale, the segregation was done for the ten departments with highest number of suburban informal settlements.

Data source:
The localization of informal settlements in Corrientes is mainly perimetral and suburban. As Map 23 shows, suburban informal settlements are found in land used for forestry. The vertical bars in the graph are proportional to the number of families. In the province of Corrientes, the Iberá Wetlands (Esteros del Iberá), which is the second largest wetland in the world, and the Humid Chaco (Chaco Húmedo) represent two ecosystems of great importance. Thanks to these, vegetation land and bodies of water flourish. There are forests in the capital zone, and crops and pastures have been developed. It is important to consider the families of suburban BPs that are situated in bodies of water (100% in San Cosmé; 53% in Saladas; and 36% in Goya) and their consequential risk of flooding. Informal settlements are also situated in forestal zones. In Map 24, we see the city of Corrientes. The neighborhoods of Pirayui and Punta Taitalo are highlighted, with 890 and 400 families, respectively.

In the city of Corrientes, informal settlements are, for the most part, located at the urban perimeter or in the suburbs. It is important to consider the families of the suburban informal neighborhoods, located near bodies of water, and the consequent risk of flooding, as well as the families of the informal neighborhoods located in forest areas.
MAP 23
ATLAS OF INFORMAL SETTLEMENTS ACCORDING TO LAND USE
Scale of Corrientes province

Percentage of informal settlements in suburban areas by province

- **ESQUINA**: Families: 155, 100%
- **LAVALLE**: Families: 190, 37% 63%
- **BELLA VISTA**: Families: 160, 71% 29%
- **Goya**: Families: 159, 64% 36%
- **LAVALLE**: Families: 160, 57% 43%
- **SALDAS**: Families: 90
- **CONCEPCIÓN**: Families: 110, 97% 3%
- **SAN COSME**: Families: 40, 100%
- **SAN LUIS DEL PALMAR**: Families: 195, 100%
- **PASO DE LOS LIBRES**: Families: 266
- **MONTE CASEROS**: Families: 25, 100%
- **SANTO TOMÉ**: Families: 250, 100%

**Land use**
- Crops
- Forests
- Bush
- Pastures
- Bodies of water
- Flooded vegetation

Data source:
MAP 24
ATLAS OF INFORMAL SETTLEMENTS ACCORDING TO LAND USE
Scale of Corrientes province

Types of informal settlements
- Suburban settlements
- Perimetral settlements
- Urban settlements

Land use
- Crops
- Forests
- Bush
- Pastures
- Bodies of water
- Flooded vegetation

Data source:
With respect to hydrological risks, the Atlas evaluated risks of floods and droughts. To the right of Map 25, we can see 483,000 families, and in CABA, Córdoba, and Santa Fe, almost 100% of informal settlements have been identified as vulnerable to risk of droughts. In Tierra del Fuego and La Pampa, essentially 100% are at risk of high floods. The plains in the east of Santa Fe are almost exclusively occupied by informal neighborhoods, precarious housing, and other modalities of vulnerable settlements. In this zone, the high risk of floods has reduced their market value, and only those who cannot afford a formal settlement settle there. Surveys also highlighted the presence of settlements inhabited by immigrants from Bolivia and Paraguay at the edges of the contaminated Reconquista River and Matanza River in Buenos Aires. They suffer the stench of still water and untreated residual waters, rat invasions, mosquitoes, flies, and other insects, in wastelands that are difficult to develop. These are not isolated risks. There are cases of informal settlements in Buenos Aires built on an old lakebed, a toxic wasteland, a cemetery, and a flood plain.

Flood risks are represented on the left in Map 25 and Graph 14. The map shows flood risks of basins in blue tones, according to the area density of informal settlements, in order to establish priorities of action. The dotted shade shows the risk of high floods. Almost 50% of informal settlements (graph below, right) is found in category 2 (mid-to-high risk) and almost 20% in 304 (high-very high), according to the data from Aqueduct. This increases floods, due to a lack in drainage infrastructure. Cities with higher risk are highlighted, according to their area of informal settlements and flood risk. The highest average of flood risk is found in Tierra del Fuego, with 100% of families at very high risk. In second place, La Pampa has a high average risk of 3.54, and 95% of families at very high risk. In third place, Chaco and Chubut have a high average risk of over 3, and almost 54% and 79% of families at very high risk.

Map 26 shows the density of informal settlements and the risk of floods per department, together with the main rivers and streams. The dotted shade shows the risk of general flooding per basin, according to data from Aqueduct. The informal neighborhoods are shown with vertical bars per city. The height represents the number of families, and the color represents the risk of flooding in each city (from grey to red, increasing in risk).

With regard to the relation between risk and flooding in the informal settlements of the province of Corrientes, Map 27 shows that the highest risk, as well as the area and number of families, will be concentrated in the capital. In the base of the map, we can see the main runoffs and bodies of water. In this case, the Ibera Wetlands are highlighted. The dotted shading shows the risk of general flooding in the basin, according to Aqueduct. The highest risk of flooding is found in the northeastern limits of the province, around the capital. Vertical bars represent the number of families, and the color gradients and patterns on the map represent the risk of flooding.

Map 28 shows the low-income neighborhoods of the city of Corrientes. At this scale, risk has been calculated from the distance from the river bank, taking into account the conditions that affect runoff velocity (slopes, topography, and land use). In the map on the left, floods from 2014 are also represented. It is important to note that this information does not include floods caused by drainage problems or lack of infrastructure, nor events in illegal settlements in bodies of water or zones of accumulation. This information is reflected in the prototype plans.

Map 29 shows the risk of drought (a significant condition with respect to climate change) and water supply infrastructure in informal settlements. In urban surroundings, it can increase greenhouse and albedo effects. The base of the map shows the risk of drought per basin and per area. In Buenos Aires, 483,000 families in CABA, Córdoba, and

MAP 26
RISK ATLAS OF INFORMAL SETTLEMENTS: FLOODING
Scale of Argentina

Risk of flooding by basins: area density of informal settlements by risk

Data source:

The map represents the quantity of informal settlements multiplied by flood risk. The darker blues imply higher quantities of families at highest risk. The grey shows the individual values of families in informal settlements of the other departments.

BUENOS AIRES
Families: 473,021
BP: 1,213
| 147.2 km²
BAHÍA BLANCA
Families: 4,740
BP: 23
| 3.4 km²
NEUQUÉN
Families: 6,028
BP: 40
| 2.8 km²
SANTIAGO DEL ESTERO
Families: 9,365
BP: 28
| 6.1 km²
GRAN RESISTENCIA
Families: 19,191
BP: 148
| 11 km²
GRAN CORRIENTES
Families: 12,315
BP: 47
| 6.3 km²
LA PLATA
Families: 59,779
BP: 187
| 19.9 km²

The map represents the quantity of informal settlements multiplied by flood risk. The darker blues imply higher quantities of families at highest risk. The grey shows the individual values of families in informal settlements of the other departments.
GRAPH 14
RISK SUMMARY OF FLOODING FOR FAMILIES AND PROVINCES

BUENOS AIRES     2.08
CATAMARCA         1.60
CHACO             3.22
CHUBUT            3.15
GREATER BUENOS AIRES     2.18
CORRIENTES        1.45
CÓRDOBA           0.50
ENTRE RÍOS        1.66
FORMOSA           2.92
JUJUY            3.25
LA PAMPA          3.54
LA RIOJA          1.87
MENDOZA           0.68
MISIONES          0.39
NEUQUÉN          3.16
RÍO NEGRO         3.01
SALTA             2.35
SAN JUAN          0.12
SAN LUIS          0.82
SANTA CRUZ        0.00
SANTIAGO DEL ESTERO     1.58
TIERRA DEL FUEGO     2.83
TUCUMÁN           1.34

Risk of flooding

- Very high risk (4)
- High risk (3 - 4)
- Medium risk (2 - 3)
- Low risk (1 - 2)
- Very low risk (0 - 1)

Data source:
The map represents the amount of informal settlements multiplied by the risk of flooding. The darkest grey implies a higher quantity of families at the highest risks.

Data source:

**MAP 26**
RISK ATLAS OF INFORMAL SETTLEMENTS: FLOODING
Scale of Bioregional Mesopotamia

Risk of flooding by basins: area density of informal settlements by risk

100

RISK OF HIGH FLOODING

0

DENSITY OF WORKING-CLASS NEIGHBORHOODS

0 1 2 3 4

13,000

**GRAN CORRIENTES**
Families: 12,315
BP: 47 | 6.1 km²

**CONCORDIA**
Families: 4,447
BP: 65 | 3.9 km²

**SAN PEDRO**
Families: 2,549
BP: 20 | 1.7 km²

**GRAN PARANÁ**
Families: 8,420
BP: 53 | 3.9 km²

**GRAN POSADAS**
Families: 17,230
BP: 86 | 6.9 km²

**ELDORADO**
Families: 2,239
BP: 11 | 2.5 km²

**PUERTO IGUAZÚ**
Families: 3,662
BP: 11 | 2.5 km²

The map represents the amount of informal settlements multiplied by the risk of flooding. The darkest grey implies a higher quantity of families at the highest risks.
**MAP 27**
RISK ATLAS OF INFORMAL SETTLEMENTS: FLOODING
Scale of Corrientes province

Data source:

The map represents the amount of informal settlements multiplied by the risk of flooding. The darkest grey implies a higher quantity of families at the highest risks.
Risk map of flooding in Corrientes, evaluated considering the distance to the river bank and the conditions that affect the velocity of runoff (slopes, topography, and land use). The map on the left represents the floods of 2014. It is important to note that this information does not include the flooding due to drainage problems because of lack of infrastructure, nor events of illegal settlements in bodies of water or zones of accumulation of bodies of water.

Data source:
Santa Fe, corresponding to almost 100% of informal settlements, are identified as vulnerable to risk of drought. In Tierra del Fuego and La Pampa, virtually 100% are at high risk of flooding. In the summary of data found in the introduction to the Atlas, Graph 15 shows the elevated number of families in high risk of drought. Here, the average risk per family and province is seen (left), where Buenos Aires and CABA have higher averages. In Buenos Aires, CABA, Córdoba, and Santa Fe, 99 to 100% of families are in high risk of drought.

In Map 30, the base of the map shows the density of informal settlements and the risk of drought per department. The dotted shade shows the risk of general drought per basin, according to Aqueduct. Informal settlements are represented by vertical bars for cities. The height represents the number of families, and the color (showing higher risk from grey to red) represents the risk of drought in each city. The southern part of the region has a higher risk of drought.

In relation to the risk of drought in the province of Corrientes, Map 31 shows the risk in drought per basin, according to Aqueduct. The vertical bars represent the families living in informal settlements, and the color gradients and patterns on the map show the risk of flooding.

Map 32 shows the risk of drought in Corrientes. The northern center of the city is at medium risk, however the surroundings are at low risk. Informal settlements are shown according to water supply, as identified by ReNaBaP. The majority have an irregular connection to the public system of running water. Those at the periphery, such as the Santa Margarita neighborhood, rely on the communal well pump.

483,000 families in Buenos Aires and close to 100% of informal settlements in CABA, Córdoba, and Santa Fe have been identified as vulnerable to the risk of drought.
The map represents the number of informal settlements multiplied by risk of drought. The darkest grey implies a greater quantity of families at highest risk.

Data source:
**GRAPH 15**

**SUMMARY OF DROUGHT RISK FOR FAMILIES AND PROVINCES**

<table>
<thead>
<tr>
<th>Province</th>
<th>Risk of drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUENOS AIRES</td>
<td>Very high risk (3-4)</td>
</tr>
<tr>
<td>CATAMARCA</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>CHACO</td>
<td>Very high risk (3-4)</td>
</tr>
<tr>
<td>CHUBUT</td>
<td>Medium risk (2-3)</td>
</tr>
<tr>
<td>GREATER BUENOS AIRES</td>
<td>Medium risk (2-3)</td>
</tr>
<tr>
<td>CORRIENTES</td>
<td>Medium risk (2-3)</td>
</tr>
<tr>
<td>CÓRDOBA</td>
<td>Very high risk (3-4)</td>
</tr>
<tr>
<td>ENTRE RÍOS</td>
<td>Medium risk (2-3)</td>
</tr>
<tr>
<td>FORMOSA</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>JUJUY</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>LA PAMPA</td>
<td>Medium risk (2-3)</td>
</tr>
<tr>
<td>LA RIOJA</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>MENDOZA</td>
<td>Medium risk (2-3)</td>
</tr>
<tr>
<td>MISIONES</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>NEUQUÉN</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>RÍO NEGRO</td>
<td>Very high risk (3-4)</td>
</tr>
<tr>
<td>SALTA</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>SAN JUAN</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>SAN LUIS</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>SANTA CRUZ</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>SANTIAGO DEL ESTERO</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>TIERRA DEL FUEGO</td>
<td>Low risk (0-2)</td>
</tr>
<tr>
<td>TUCUMÁN</td>
<td>Low risk (0-2)</td>
</tr>
</tbody>
</table>

**Data source:**
The map represents the amount of informal settlements multiplied by risk of drought. The darkest grey implies a greater quantity of families at highest risk.

Data source:
MAP 31
ATLAS OF RISKS IN INFORMAL SETTLEMENTS: DROUGHT
Scale of Corrientes province

Risk of droughts by basins: area density of informal settlements by risk

Data source:
MAP 32
ATLAS OF RISK IN INFORMAL SETTLEMENTS: DROUGHT
Scale of Gran Corrientes

Risk of droughts by basins: area density of informal settlements by risk

- High risk
- Medium risk
- Low risk

Types of Water supply
- community well water pump
- community tap within the neighborhood
- irregular connection to the public water system
- regular connection to running water from the public system but without bottle/bill
- formal connection to public running water main

Data source:

ECOLOGICAL DESIGN

ECOLOGICAL DESIGN
Hydrous erosion is analyzed in Map 33 and Graph 16. To evaluate the risk of hydrous erosion of the land, the Revised Universal Soil Loss Equation (RUSLE) was used, which predicts the annual loss of land from rain and water runoff. This is the most common model, used by large-scale spaces due to its relatively simple structure and empirical basis. The model takes into account: (1) rain erosion, (2) climate classification, (3) soil data, (4) elevation data, and (5) soil cover data. It is important to highlight, with respect to land in the informal settlements, that land contamination has not been evaluated, due to lack of data availability. Many informal settlements are situated in areas that are contaminated by garbage dumps or industrial waste with no treatment. Risk of illness is high and is multiplied by conditions of climate change such as flooding, drought, or land erosion. These maps show erosion according to the RUSLE average per province (above) and the territory in their different degrees (below). The most affected provinces are Buenos Aires (over 31,000 families), Córdoba, Santa Fe (almost 27,000 families), and Tucuman. The black bars show the total number of families, and the red shows the total number of families affected by the highest levels of erosion.

Map 34 shows hydrous erosion of the land in Mesopotamia. This gradient is assigned to informal settlements according to their situation. The height indicates the number of families affected in each neighborhood. The thick bars with labels show the number of families affected in cities, and the color represents the average erosion in all the informal settlements. The city of Gran Parana is highlighted for its level of risk. The province of Corrientes has less risk of land loss than Entre Rios and Misiones, where there is higher forest loss and higher use of cultivated soil.

Many informal neighborhoods are located in areas with soil that is contaminated by garbage dumps or untreated industrial waste. The risk of diseases is high and multiplies with the effects of climate change, such as floods, drought, or soil erosion.
1. RAIN DATA (Worldclim)
The emissivity of rain is the kinetic energy of the impact of the raindrop and the rate of runoff associated with it.

Rain emissivity in Argentina (MJ/ha·mm)

- Misiones: 7831.3
- Corrientes: 5681.9
- Chaco: 4671.7
- Formosa: 4375.3
- Santa Fe: 4373.1
- Entre Ríos: 4078.5
- Córdoba: 3871.9
- Santiago del Estero: 3715.7
- Tucumán: 3461.8
- Salta: 3116.4
- San Luis: 2853
- Buenos Aires: 3570
- Jujuy: 2133.3
- La Pampa: 2053.6
- La Rioja: 1733.4
- Catamarca: 1565.4
- Mendoza: 1130.9
- San Juan: 1118.3
- Neuquén: 615.4
- Río Negro: 479.9
- Santa Cruz: 466.6
- Chubut: 375.9

2. CLIMATE CLASSIFICATION OF KÖPPEN-GEIGER
The climates are divided into five principal climate groups, and each group is subdivided according to the seasonal patterns of precipitation and temperature. The five principal groups are A (tropical), B (dry), C (temperate), D (continental), and E (polar).

Climate classification in Argentina

- E: 5.1%
- B: 40.6%
- C: 54.2%

3. SOIL DATA
Harmonized World Soil Database v1.2 (HWSD) is a database of 30 seconds of arc with over 15,000 mapping units of different types of soil that combine the regional and national information updates in soil across the world.

4. ELEVATION DATA
(USGS, TopoTools, NGDC NOAA)

5. LAND COVER DATA
(GlobCover 2009)
MAP 33
RISK ATLAS OF HYDROUS SOIL EROSION
Scale of Argentina

Data source:
World Resources Institute; Rain data: WorldClim.org; Soil data: (HWSD) FAO; Elevation data: USGS, TopoTools, NGDC NOAA; Land Cover Data: GlobalCover 2009.
Visualizing the dynamics of ecosystems in which the settlements of popular neighborhoods occur is vital for the design of green infrastructure strategies.
ATLAS OF INFORMAL SETTLEMENTS BY ECOREGIONS AND PROTECTED AREAS

Scale of Argentina

Ecoregions and protected areas
- Patagonian forests
- Yunga forests
- Alto Paraná Atlantic forests
- Mountain ranges and bolsones
- Dry Chaco
- Argentine Espinal
- Malezal rangelands
- Pampa
- Humid Chaco
- Delta and islands of Parana
- Ibera marshes
- Patagonian steppe
- Mountain of plains and plateau
- Puna
- Protected areas

Data source:
Risk Summary of Families in Protected Areas

Data source:
ReNaBaP (2018), Relevamiento Nacional de Barrios Populares 2018; APN (2017), Ecoregiones de Argentina; IN (2019), Protected Areas of the Argentine Republic.
Lastly, the Atlas explores the level of fragmentation in landscapes where informal settlements are settled. This is seen in Map 36. The protection of natural landscapes increases the resilience of urban surroundings. Deforestation and loss of bodies of water carries with it fragmentation of landscapes, loss of biodiversity, reduction of ecosystem services like carbon absorption, and increases in hydrous fragility. The lower map represents informal settlements that are found in a radius of 25km of deforested areas (in green), water loss (blue), or both (purple). In the map above, metric calculations are shown in percentages of neighborhoods affected in the most affected province. Buenos Aires is highlighted for its number of families and, in second place, Santa Fe and CABA. In the cases of Buenos Aires, Chubut, CABA, La Pampa, Mendoza, Neuquén, Río Negro, San Juan, Santa Cruz, Santa Fe, and Tierra del Fuego, 100% of the surveyed families reside in areas of water loss, and many of them coincide with risk of drought. In Catamarca and La Rioja, 100% of fragmented landscape zones, where families of informal settlements live, are in zones of deforestation, which increases the vulnerability of territories to droughts and extreme climatic events. In Santiago del Estero, Formosa, and Corrientes, there is a high percentage of mutual overlapping. The risks of landscape fragmentation are associated with the loss of resilience to drought and extreme climatic events, caused either by deforestation or a decrease in bodies of water, or the invasion of unsinkable basins. Deforestation is an unnatural risk that contributes to land erosion and to vulnerability to floods, as the vegetation slows down erosion and increases soil filtration, preventing its erosion. Additionally, there is a loss of carbon sinks, causing the disappearance of entire ecosystems that contribute to biodiversity. The loss of bodies of water can also increase these phenomena, as can droughts, with risks to health and social well-being. The Atlas shows informal settlements in these zones or their surroundings. This is one of the larger risks that affect informal settlements, as in the majority of the provinces, almost 100% of informal settlements are found in fragmented landscapes. In the case of Catamarca and La Rioja, 100% are close to zones of deforestation. In Buenos Aires, CABA, Mendoza, Chubut, Neuquén, Río Negro, and other provinces, 100% are located near zones where bodies of water are disappearing. Santiago del Estero and Corrientes are highlighted for their proximity to both types of zones.

The invasion of natural reserves, protected basins, and green belts is another of the risks associated with fragmentation. The invasion of these zones causes a loss of continuity and therefore a loss of ecosystem services or benefits and the functions they provide: greenhouse gas absorption, protection from floods, air quality, soil protection, etc. Although this persists while urban plans and building are being developed, the risks for the inhabitants of informal settlements that are already in vulnerable situations are worsened. In the province of Chaco, over 17,000 families are found in protected landscapes, and over 5,000 in Buenos Aires. In Tierra del Fuego, over 60% of informal settlements are settled in natural reserves. In order to design a resilient infrastructure from natural principles, it is important to know the landscapes and natural dynamics of what is inserted (vegetation, types of soil, hydraulic systems, etc.) The Atlas includes a map of the natural landscapes in Argentina in order to situate informal settlements in their natural context, restore a connection with the territory, and generate landscape resilience.

In the central map in Map 37, there is a 25 km radius of influence for the loss of bodies of water (the southern and central limits of the region of Mesopotamia are predominant), the loss of forests (mainly in Entre Ríos y Misiones), and both water and forest loss (which can be seen in the eastern edge along the Parana River). In the region, there is a great variety of landscapes and biodiversity (below), where wetlands in the Ibera Wetlands are highlighted (light blue), the delta and islands of Parana (middle blue), and the Humid Chaco (dark blue). At the bottom of the upper map, there is the base percentage of informal settlements in zones of total loss, by department, and in the bars, the number of families and
The risks that popular neighborhoods face – low quality of public space and services – can be reduced through the implementation of nature-based solutions, much like the recovery of local landscapes (forests, wetlands, grasslands).
MAP_36
ATLAS OF INFORMAL SETTLEMENTS IN FRAGMENTED LANDSCAPES
Scale of Argentina

Quantity of informal settlements that are near deforestation and permanent water loss by province

- Deforested areas and water loss
  - Deforested areas
  - Zone close to deforestation (25km radius)
  - Areas with water loss
  - Zone close to water loss (25km radius)
  - Intersection between deforested areas and water loss

Percentage of informal settlements by zones of loss

Data source:
ReBaNN (2018), Relevamiento Nacional de Barrios Populares 2018; APN (2017), Ecoregiones de Argentina; IN (2019), Protected Areas of the Argentine Republic.
### Risk Summary of Families in Fragmented Landscapes

**Data Source:**
- ReNaBaP (2018), Relevamiento Nacional de Barrios Populares 2018; APN (2017), Ecoregiones de Argentina; IGN (2019), Protected Areas of the Argentine Republic.

**Deforestation, water loss or both**

#### Distribution of Families by Province:

<table>
<thead>
<tr>
<th>Province</th>
<th>Families</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buenos Aires</td>
<td>393,711</td>
</tr>
<tr>
<td>Catamarca</td>
<td>2,790</td>
</tr>
<tr>
<td>Chaco</td>
<td>32,670</td>
</tr>
<tr>
<td>Chubut</td>
<td>4,746</td>
</tr>
<tr>
<td>Greater Buenos Aires</td>
<td>73,673</td>
</tr>
<tr>
<td>Corrientes</td>
<td>17,956</td>
</tr>
<tr>
<td>Córdoba</td>
<td>22,541</td>
</tr>
<tr>
<td>Entre Ríos</td>
<td>17,836</td>
</tr>
<tr>
<td>Formosa</td>
<td>18,594</td>
</tr>
<tr>
<td>Jujuy</td>
<td>10,138</td>
</tr>
<tr>
<td>La Pampa</td>
<td>10,158</td>
</tr>
<tr>
<td>La Rioja</td>
<td>10,360</td>
</tr>
<tr>
<td>Mendoza</td>
<td>10,026</td>
</tr>
<tr>
<td>Misiones</td>
<td>17,836</td>
</tr>
<tr>
<td>Neuquén</td>
<td>10,246</td>
</tr>
<tr>
<td>Río Negro</td>
<td>16,379</td>
</tr>
<tr>
<td>Salta</td>
<td>20,195</td>
</tr>
<tr>
<td>San Juan</td>
<td>2,858</td>
</tr>
<tr>
<td>San Luis</td>
<td>3,027</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>1,048</td>
</tr>
<tr>
<td>Santa Fe</td>
<td>71,170</td>
</tr>
<tr>
<td>Santiago del Estero</td>
<td>11,295</td>
</tr>
<tr>
<td>Tierra del Fuego</td>
<td>34,847</td>
</tr>
</tbody>
</table>

**Additional Notes:**
- Families are listed as ‘Familias’.
- The diagram visually represents the risk summary with different segments indicating deforestation, water loss, and both.

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**Graph 18:**

**EcoDesign**

IDB

**ECOLOGICAL DESIGN**

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Quantity of informal settlements in areas close to permanent deforestation and water loss by province

- Deforested and water loss areas
  - Deforested areas
  - Zones close to deforestation (25km radius)
  - Water loss areas
  - Zones close to water loss (25km radius)
  - Zones of intersection between deforested areas and water loss
  - Protected zones

Percentage of informal settlements by zones of loss

Data source:
Reilhaer (2018), Relevamiento Nacional de Barrios Populares 2016; APN (2017), Ecoregiones de Argentina; IN (2018), Protected Areas of the Argentine Republic.
MAP 38
ATLAS OF INFORMAL SETTLEMENTS IN FRAGMENTED LANDSCAPES
Scale of Gran Corrientes

Quantity of informal settlements in areas close to deforestation and permanent water loss by province

<table>
<thead>
<tr>
<th>Location</th>
<th>Families</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SANTO TOMÉ</td>
<td>230</td>
<td>100%</td>
</tr>
<tr>
<td>CORRIENTES</td>
<td>14,075</td>
<td>100%</td>
</tr>
<tr>
<td>CONCEPCIÓN</td>
<td>1,710</td>
<td>100%</td>
</tr>
<tr>
<td>PASO DE LOS LIBRES</td>
<td>451</td>
<td>100%</td>
</tr>
<tr>
<td>MERCEDES</td>
<td>182</td>
<td>100%</td>
</tr>
<tr>
<td>SALADAS</td>
<td>224</td>
<td>100%</td>
</tr>
<tr>
<td>LAVALLE</td>
<td>190</td>
<td>100%</td>
</tr>
<tr>
<td>BELLA VISTA</td>
<td>324</td>
<td>100%</td>
</tr>
</tbody>
</table>

Data source:
ReNaBaP (2018), Relevamiento Nacional de Barrios Populares 2018; APN (2017), Ecoregiones de Argentina; IGN (2019), Protected Areas of the Argentine Republic.
MAP 39
ATLAS OF POTENTIAL RESILIENT LANDSCAPES
Scale of Argentina

Types of landscapes
- Informal settlements
- Crops
- Forests
- Pastures
- Bodies of water

Data source:
Local landscapes such as forests, marshes, pastures, etc., generate benefits, such as an increase in storage capacity, filtration, and water recycling; an increase in biodiversity and ecological wealth; soil recovery and carbon storage in soil and vegetal species, among others. On the Mesopotamian scale, the sequence of maps in Map 40 show how the existing reserves of forests and marshes can serve as anchors and, potentially, connect green infrastructure interventions in urban areas.

The strategy can be replicated on the scale of the province of Corrientes, which is seen in Map 41. The existing local reserves can work as anchors to expand landscapes along the provincial hydrological network. The expansion of resilient local landscapes benefits low-income neighborhoods, if green infrastructure that is implemented in them is connected or is directly linked to these ecological corridors. The interconnection between the low-income neighborhoods and resilient landscapes assures that the neighborhoods can get access to ecological benefits that involve the landscapes. They can also guarantee the mitigation of extreme events such as floods or heat-island effects in the short, medium, and long term.
MAP 40
ATLAS OF POTENTIAL RESILIENT LANDSCAPES
Scale of Bioregional Mesopotamia

Types of landscapes
- Informal settlements
- Crops
- Forests
- Pastures
- Bodies of water
- Protected areas

Data source:
MAP 41
ATLAS OF POTENTIAL RESILIENT LANDSCAPES
Scale of Gran Corrientes

Types of landscapes
- Informal settlements
- Crops
- Forests
- Pastures
- Bodies of water
- Protected areas

Data source:
In the next chapter, we will focus on case studies in LAC. Possible responses to the thematic evidence of the Atlas are proposed, imagining different models of development that can integrate existing informal infrastructures.\footnote{Satthertwaite, D. et al. (2018).} Es importante considerar la ciudad espontánea y los barrios populares, no como componentes marginales de las ciudades, sino más bien como áreas en continua transformación, que contribuyen a la economía de las ciudades y países y que, como tales, deberían ser parte de las políticas de mejoramiento de calidad urbana y adaptación al cambio climático; ser parte de planes futuros.\footnote{See in the following paragraphs the concept of “informal armor” by David Gouverneur and the following texts: Robleto, L. (2013, July 1). David Gouverneur, interviewed by Leo Robleto Constante. Landscape strategies for informal settlements: Creating armatures to shape urban form. Metropolis Mag. Gouverneur, D. (2016). Diseño de nuevos asentamientos informales. Eafit University Editorial Fund, Unisalle Editions.} It is important to consider the spontaneous city and informal settlements not as marginal components of cities, but instead as areas in constant transformation. They contribute to the economy of cities and countries and should therefore be part of the politics of improvement of urban quality and adaptation to climate change, becoming part of their future plans.\footnote{The strategies presented in the coming pages offer alternatives in order to improve resilience in the most vulnerable neighborhoods, through multiscale and multifunctional landscape projects and nature-based solutions. These same strategies, implemented by many actors and with multiple scopes, can be used to imagine scenarios of urban development that benefit different urban realities in the region.} The strategies presented in the coming pages offer alternatives in order to improve resilience in the most vulnerable neighborhoods, through multiscale and multifunctional landscape projects and nature-based solutions. These same strategies, implemented by many actors and with multiple scopes, can be used to imagine scenarios of urban development that benefit different urban realities in the region.
PUBLIC SPACE:
DEVICES TO REMEDIATE
THE VULNERABLE CITY
WITH NATURE
GREEN INFRASTRUCTURE AS URBAN REGENERATOR IN RESPONSE TO THE CLIMATE CRISIS

The awareness of the planet’s vulnerability has offered new layers and inputs to urban design. Among these, the need to increase the resilience of urban and coastal zones to climate change, reduce and absorb CO2 emissions, and protect biodiversity. There is an increased emphasis on the importance of integral and intersectoral projects, such as landscape urbanism projects, green and blue infrastructure, and nature-based solutions.

Latin America represents over 50% of global biodiversity, including 178 ecological regions. Some of the world’s most biodiverse countries – Brazil, Colombia and Peru – are found in this region. However, changes in land use have increased the loss of habitats in six critical points in the biodiversity of the region: Mesoamerica, Chocó-Darien-Western Ecuador, the Tropical Andes, Central Chile, the Brazilian Atlantic Forest and the Brazilian Cerrado. The climate crisis is modifying temperatures, changing precipitation patterns, and modifying seasons. Green infrastructures can play a fundamental role in improving the resilience of Latin American cities facing climate change, while providing benefits on multiple scales and functions: improving the quality of public spaces, reducing the effects of heat islands, improving the efficiency of water use and maintenance costs, protecting and increasing biodiversity, and above all improving quality of life. In this section, we will focus on nature-based solutions and green infrastructure as a means through which to improve resilience to climate change in the informal city, through low-cost and easily implemented solutions and large-scale, long-term plans.

4. Among the main effects of climate change in Latin America and the Caribbean, a 0.5°C to 3°C rise in average temperature between 1901 and 2012, when the tropical areas of South America registered the main increase in temperatures; a gradual increase in precipitation in the southeastern and northern areas of South America and in the coastal areas of Peru and Ecuador; a decrease in precipitation in the majority of the Chilian territory, in the North of Argentina, the South of Mexico and part of Central America; a progressively later start to the rainy seasons in Central America; a rise in the space and time variability of the rains, and a rise in events of intense precipitation at the start of the season. Vásquez, A. et al. (2019), p. 334.
The term green infrastructure is defined as a system of urban support focused on nature that can help respond to urban and climate challenges. Green infrastructure can manage rainwater, reduce heat wave effects, increase biodiversity, and improve the quality of air, water, and soil. Some ways in which green infrastructure can help include: more efficient uses of scarce hydric resources; restoration of natural flood defenses; using tree species and forestry practices that are less vulnerable to storms and fires; implementing natural means of water retention; reducing heat islands in urban areas; and reserving land corridors to help species migrate.

Some of the elements that define green infrastructure and improve their functioning are the creation of networks or systems, such as spatial connections that allow for the movement of people, fauna, wind, and water — for example, through the creation of corridors for pedestrians or cyclists (such as entire streets) that include green areas. Not only as a landscape factor, but as a provision of ecosystem services. Because they have an ecosystem function, green infrastructures are considered to be nature-based solutions (NBS) through the provision of ecosystem services that can contribute to the mitigation of and/or adaptation to climate change, while also providing various environmental, social, and economic benefits. Green infrastructures work, and should work, at multiple scales, connecting the regional dimension and dynamics to the local scale of the neighborhood or city. Due to their multifunctionality and the multiple scales on which they work, green infrastructures also include a plurality of actors in their planning, implementation, and maintenance.

9. Ibid.
Graph 19 shows the main types of spaces in which green infrastructure can be implemented, such as rooftops, squares, patios, suburban areas, or infrastructure areas. Also shown are the techniques used and the benefits of each, for example: green roofs and facades, potted plants with infiltrations, permeable pavements, rain gardens, permaculture, wetlands, and linear tree ditches. 11 Graph 20 highlights the main benefits of green infrastructure and the risks they face in relation to five key aspects – society and health, ecosystems, air and temperature, water quality, and economic impacts – and their impact on a global, regional, neighborhood, and domestic scale. For example, urban productive gardens that can be implemented at all scales can provide sustainable food, improve the fertility of the soil and the air quality, and can benefit social and educational activities. In this way, they help mitigate social and biological vulnerability, reducing the risk of food shortages and chronic diseases. They can even prevent epidemics and massive migrations. On the other hand, the generation of permeable surfaces in places like parks or the rooftops of buildings can contribute to the increasing of infiltration, decreasing the impacts of floods, reducing landslides, managing and cleaning water, and increasing availability of water for domestic use, in this way reducing the risk of flooding as well as shortages and poor quality of water.12


The multifunctionality of green infrastructure also translates into economic benefits, as shown in Graph 21. To the left, we can see a selection of the main techniques of green infrastructure and the indices quantifying the benefits. For example, it is estimated that every m2 of green roofing allows for an average of 10.9 l of water to be saved a year; and absorbs 0.6 g of CO2, 1.8 g of NO2 and 3.68 g of O3. Each tree absorbs 5.035 g of CO2 a year, and allows for the generation of 52.4 Kwh of energy by natural gas per year.13 To the right, the additional benefits are represented by qualitative variables according to direct, indirect, optional, future, and existential values. For example, as well as ensuring an increased availability and quality of water, green roofs can generate an indirect value in the reduction of flooding and necessity to build grey infrastructure; preserving resources for future generations; improving insulation of buildings and interior comfort; reducing the effects of heat islands due to increased albedo; and generating new cultural, aesthetic, and community values due to the activities that can be undertaken on green roofs, such as urban agriculture (that can also generate additional economic benefits).14


14. Fuente de los datos de infografía: Carne y Bass, 2008; Yang, Quan y Gong, 2008; Getter et al., 2009; CNT, 2009; IPCC, 2007; Databank Banco Mundial; s.n., Sustainable Technologies Evaluation Program, 2020.
The generation of permeable surfaces in places like parks or the rooftops of buildings can contribute to the increasing of infiltration, decreasing the impacts of floods, reducing landslides, managing and cleaning water, and increasing availability of water for domestic use, in this way reducing the risk of flooding as well as shortages and poor quality of water.

<table>
<thead>
<tr>
<th>ENVIRONMENTAL BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon and Energy Savings</td>
</tr>
<tr>
<td>Rise in Biodiversity</td>
</tr>
<tr>
<td>Improved Microclimate</td>
</tr>
<tr>
<td>Management of cleaner waste</td>
</tr>
<tr>
<td>Secure integration of water into Aquifer</td>
</tr>
<tr>
<td>Decreased heat island effect</td>
</tr>
<tr>
<td>Reduction in noise pollution</td>
</tr>
<tr>
<td>Cleaner air</td>
</tr>
<tr>
<td>Cleaner water</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>URBAN BENEFITS</th>
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</thead>
<tbody>
<tr>
<td>Pressure Reduction in the Road Infrastructure</td>
</tr>
<tr>
<td>Flood reduction and water escape in streets</td>
</tr>
<tr>
<td>Increase in economic activity</td>
</tr>
<tr>
<td>Place Identity</td>
</tr>
<tr>
<td>Reduction of unused land</td>
</tr>
<tr>
<td>Pressure reduction in urban infrastructure</td>
</tr>
<tr>
<td>Increase in value of property</td>
</tr>
<tr>
<td>Flood risk reduction</td>
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<table>
<thead>
<tr>
<th>COMMUNITY BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less energy use</td>
</tr>
<tr>
<td>Increased access to water</td>
</tr>
<tr>
<td>Space for social development</td>
</tr>
<tr>
<td>Increase in mobility</td>
</tr>
<tr>
<td>Sustainable mobility</td>
</tr>
<tr>
<td>Heating and Cooling aid</td>
</tr>
<tr>
<td>Food safety / Local products</td>
</tr>
<tr>
<td>Improved well-being</td>
</tr>
<tr>
<td>Improved visual amenities</td>
</tr>
<tr>
<td>Decrease in crime rates</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>CULTURAL AND ECONOMIC BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in attractiveness of streets and commercial spaces</td>
</tr>
<tr>
<td>Opportunities for the green industry</td>
</tr>
<tr>
<td>Creation of educational opportunities</td>
</tr>
<tr>
<td>Agricultural opportunities</td>
</tr>
<tr>
<td>Increase in land productivity</td>
</tr>
<tr>
<td>Institute identity / icon-making</td>
</tr>
<tr>
<td>Greater internal investment</td>
</tr>
<tr>
<td>Health savings</td>
</tr>
</tbody>
</table>

**Sustainable agricultural food provision**
- Increase in soil fertility
- Reduction of mortality from respiratory diseases
- Cultural and educational production on conservation
- Socio-environmental resilience and improvement
- Greater social cohesion
- Greater access to recreational spaces
- Aesthetic improvement of the landscape integration uses
- Physical and psychological well-being
- Improves habitability conditions
- Greater abundance and wealth of species
- Greater genetic diversity
- Increased carbon sequestration
- Biological control of pests
- Habitat recovery
- Improved ecosystem health
- Recovery of spaces with ecourban symbiosis
- Greater connectivity between urban and rural spaces
- Reduction of greenhouse gases CO2
- Energy saving
- Reduction of noise pollution
- Wind attenuation
- Reduction of atmospheric pollutants
- Thermal comfort
- Albedo effect reduction
- Maximum temperature reduction
- Sustainable mobility
- Greater access to water for domestic use
- Manage, clean and recycle water
- Runoff reduction > landslides
- Flood attenuation
- Increase in infiltration
- Greater provision of timber resources
- Avoided costs for the provision of natural resources
- Creation of temporary jobs for the implementation of IV
- Tourism sector growth
- Greater willingness to pay for environmental services
- Avoided maintenance costs / public investment optimization
- Increase in residential value

**Data source:** Quiroz Benítez, Diana Esmeralda. 2018. “Infraestructura Verde Como Estrategia Para La Mitigación y Adaptación Al Cambio Climático En Ciudades Mexicanas: Hoja de Ruta.” Mexico City.


### ECONOMIC ADVANTAGES OF GREEN INFRASTRUCTURE

#### Quantitative variables

<table>
<thead>
<tr>
<th>Green roofs (1m²)</th>
<th>Water [lts/year]</th>
<th>CO₂ [g/year]</th>
<th>NOX [g/year]</th>
<th>SO₂ [g/year]</th>
<th>PM10 [g/year]</th>
<th>Electric Energy [kWh/year]</th>
<th>Natural Gas [Btu/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.9</td>
<td>0.6</td>
<td>1.8</td>
<td>1.5</td>
<td>3.68</td>
<td>3.68</td>
<td></td>
</tr>
</tbody>
</table>

| Tree plantation profit per 1 tree | 0.1 | 5,034.8 | 7.7 | 47 | 22 | 29 | 18 | 92.4 |

| Rain gardens (1m²) | 93.9 |

| Permeable pavements (1m²) | 0.6 |

| Water harvest (rooftops, wetlands, etc.) (1m²) | 0.6 |

#### Qualitative variables

- Water treatment reduction
- Improved water quality
- Less need for gray infrastructure
- Flood reduction
- Greater availability of water
- Greater aquifer recharge
- Reduction in the use of water
- Reduction in the use of salt
- Reduction in the use of electrical energy
- Improved air quality
- Atmospheric CO₂ reduction
- Reduced heat island effect
- Scenic improvement
- Increase in recreational spaces
- Less noise pollution
- Greater community cohesion
- Urban agriculture
- Habitat improvement
- Public environmental education
- Provision of food

#### Data source:

#### Economic advantages of green infrastructure

<table>
<thead>
<tr>
<th>Graph 21</th>
<th>ECONOMIC ADVANTAGES OF GREEN INFRASTRUCTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantitative variables</td>
</tr>
<tr>
<td></td>
<td>Qualitative variables</td>
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</table>

<table>
<thead>
<tr>
<th>Litres/year</th>
<th>Grams/Year</th>
<th>kWh/Year</th>
<th>Btu/year</th>
</tr>
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<tbody>
<tr>
<td>&gt;11.1</td>
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</tbody>
</table>
Across the world, open spaces are being transformed into a testing ground for implementing nature-based solutions and green infrastructure. In New York, for example, the main transformations of public spaces that are being developed use elements of green infrastructure to increase the resilience of the city. As a result of the Obama initiative, the Hurricane Sandy Rebuilding Task Force launched an innovative design competition, Rebuild by Design, that fomented different visions to make cities and coastal areas more resilient.15 These transformations include large projects in the most important parts of the city, such as BIG U, in Lower Manhattan,16 but also extensive ecological projects for the most peripheral and low-income areas. Living Breakwater, Scape’s project for the southern coast of Staten Island, proposes interventions that improve the resilience of the coast, and considers the involvement of the local community.17 From this projects, an institution was formed, providing funds to build resilient infrastructure for the entire state of New York. According to data contributed by Rebuild by Design, for each dollar invested in green infrastructure, six dollars are saved in the expenses of future events of natural disasters.18 Other studies developed in the United States show how, in the absence of natural disasters, green infrastructure and in particular trees, present great economic benefits valued at around $1.37 to $3.09 for every dollar invested.19

In China, the Turenscape firm has developed over 300 ecological cities and 1,000 landscape projects such as wetlands, parks, and ecological corridors, in order to mitigate the impacts of massive urbanization and industrialization.20 In Europe, the European Commission is promoting the initiative Green Infrastructure Strategy in order to integrate adaptation of ecosystem-based solutions into public policies for climate change. These include the incorporation of nature-based solutions into research and innovation policies; natural measures for water retention in water policies; and solutions that can provide multiple ecosystem services and rich biodiversity in nature policies.21

Across the world, open spaces are being transformed into a testing ground for implementing nature-based solutions and green infrastructure.

Parque Fluvial de las Familias, Santiago de Chile


17. Starting from a previous project called Oyster-tecture that Scape proposed for the exhibition, Rising Currents at the MoMA (Bergdoll, 2010), Living Breakwaters uses a ring of breakwaters to protect the local inhabitants from the damage and erosion caused by waves. Meanwhile, it provides a more diverse habitat for young fish, eels, and other organisms. The living infrastructure is coupled with infrastructure for local resilience of the neighborhoods adjacent to the coast, to help increase awareness of risks, empowering the citizens and stimulating local schools to teach about the coastal fronts.


20. For the environmental benefits of projects by Turenscape in China, see the document published by the Inter-American Development Bank: Paquete de soluciones de infraestructura verde urbana reto, oportunidades y manual de buenas practicas (2019). See also: www.turenscape.com

Latin American cities are also investing in large-scale urban landscape projects that are able to integrate ecological infrastructure, various networks, and high-quality public spaces, such as the regeneration of Río Medellín in Colombia, the Parque Dom Pedro II in São Paulo, or the Paseo Cívico Metropolitano in Santiago, Chile. The three projects are located within metropolitan areas, combining the possibility of integrating different types of urban mobility (public transport, bicycle routes, and pedestrian areas) with a regeneration of the riverbanks adjacent to urban areas. They offer environmental benefits and recreation areas at a local, neighborhood level, as well as at a city level, reducing and absorbing emissions and improving accessibility to services.22 Various authors highlight how Latin American cities have traditionally supported urban projects that generate social segregation by creating the conditions for the real estate industry to take over central and pericentral areas, pushing the original residents to more marginal areas. This causes a territorial reconfiguration and change in the city in terms of its uses, accessibility, and identity. It also reflects the spatial injustice that questions the right to the city, while confronting two types of cities: the elitist city and the informal city.23 The projects mentioned before are examples of urban infrastructure that acknowledge this condition and try to reverse it by extending services and accessibilities to the whole metropolitan area. In this document, we are particularly interested in exploring how green infrastructure can improve the informal city through tactical interventions, to be applied in the short-term and with relatively limited resources, as well as through large-scale and long-term planning.


As mentioned in the previous chapters, climate change presents an increasing risk factor for precarious settlements with high levels of informality, as its effects are added to conditions of congenial vulnerability and limited access to resources. In this chapter, we focus on the relevance of adopting nature-based solutions in public spaces within the most vulnerable settlements. The relevance of green infrastructure depends on the elements that shape its reason for being, the ability of natural and semi-natural areas to offer ecosystem services in the city, to offer connections between the city and recreational spaces, all of which also provide environmental, social, and economic benefits.  


25. Graph 13. Green areas and socioeconomic levels: Buenos Aires. The m2 of green areas per inhabitant are elaborated from the layer “green areas” available on the page Buenos Aires Data, matched up with the projection of the population for 2019 by the DGEEC. On the page, it is indicated that the layer of green spaces in the city includes “garden, park, recreational patio, square, small squares, and multiple sports clubs”. The socioeconomic level per neighborhood is elaborated from the percentages of socioeconomic levels per neighborhood, from the social dimension in the Modelo Territorial de Buenos Aires. Here, the population is divided into six levels that synthesize the incomes with data related to education, occupation, qualification and work category, and characteristic of the home.

26. Graph 13. Green areas and socioeconomic levels: Medellín. The m2 of green areas per inhabitant are elaborated from the layer, “existing public areas”, available on the page Open Data from the Medellín Council, matched up with the projection of the population for 2018 from the same source. The page indicates that the layer of existing public space is the existing space for entertainment and gatherings from the active Plan de Ordenamiento territorial (Irrigation Plan) and that corresponds to effective public space of a permanent nature, destined for recreation, leisure, and gatherings, for collective use. The average socioeconomic level per municipality is elaborated from a publication by the Munit-Izq quality of Medellín that distributes housing into six socioeconomic levels. There is a clear relationship between the density of public space and socioeconomic levels, with the exception of Roblello, a municipality of lower income and higher density of green areas, in the periphery, and El Poblado, with the highest income and fewest green areas located in the center.

27. Graph 13. Green areas and socioeconomic levels: Santiago, Chile. The m2 of green areas per inhabitant are elaborated from the graph “Superficies de áreas verdes públicas por habitante” published on the page. Sistema de Indicadores y Estándares del Desarrollo Urbano (SIEDU), showing “the relationship between the total surface of communal green areas (public parks and squares) and the urban population by municipality”. The average percentage is elaborated from the percentages of socioeconomic levels of the Indicador de Bienestar Territorial, distributing the population of each municipality into 10 socioeconomic centiles. The density of public green areas is directly related to social levels, diffused in some municipalities at the center (Santiago, Ruiz, Independencia, and San Miguel), as well as San Ramón, Lo Espejo, and La Pintana in the extreme opposite, at the southern limit of the city.

28. Graph 13. Green areas and socioeconomic levels: São Paulo. The m2 of green areas per inhabitant are elaborated from the graph “Área verde por hab. de 2017”, published on the page of the Rede Social Brasileira by Cidades Justas e Sustentáveis. The indicator of m2/hab of green areas is obtained from the green areas of public property, created and administered by the municipal government and the state government, including all municipal public parks, state public parks, squares, and all the Unidades de Conservação de Proteção Integral (protected areas) defined by the Sistema Nacional de Unidades de Conservación. The average percentage of socioeconomic levels is elaborated from the Indice Paulista de Vulnerabilidad Social (IPVS), that divides the population into seven socioeconomic levels. We can see São Paulo has a high density of green areas in some of its municipalities. We can also see a direct relationship in the diagonal between Vila Mariana and Capela do Socorro, with certain exceptions of high income and low density of green areas below this line. The pattern observed in the other cities, with the exception of the municipalities of lower income and higher density of green areas in the periphery, and higher socioeconomic levels with fewer green areas in the center, cannot be seen in São Paulo, as the lower socioeconomic levels are located in the center.

The distribution of nature and high-quality public spaces is extremely unequal between the formal and the informal city. This has historic references: when a large part of the population moved to metropolis such as Medellín, Bogotá, Santiago de Chile, and São Paulo, during the 20th century, the antagonism between the urban and the rural, the formal and the informal was replicated within the area of the city, as were economic inequalities. The maps on Graphs 22 to 25 show the relationship between green areas and socioeconomic levels in Buenos Aires, Medellín, Santiago, and São Paulo. In Bueno Aires, for example, with the exception of a few neighborhoods, the relationship between m2/inhabitant of green spaces and the average socioeconomic level seems to be organized in two parallel curves. There is a tendency toward more m2/inhabitant in relation to a higher average socioeconomic level. The low-income neighborhoods with a higher density of green areas are located in the periphery while the neighborhoods characterized by a higher socioeconomic level with lower density of green areas are located in the most central areas. Also in Medellín, there is a clear relationship between green areas and income, as there is in Santiago and São Paulo, except for central neighborhoods that are characterized by high income and a lack of green areas.
**GRAPH 22**
GREEN AREAS AND SOCIOECONOMIC LEVEL
Medellín

**GRAPH 23**
GREEN AREAS AND SOCIOECONOMIC LEVEL
Buenos Aires

Data source:
- Mayor of Medellín (2012), Stratification socioeconomic housing; Mayor of Medellín open data (2018), Public space existing; Mayor of Medellín (2016), Population Projections 2016 to 2020 from Medellín (2018 used).
Data source: District Planning Secretary (2014), Socioeconomic characterization, survey SISBEN III
Open Data Bogotá (2020), Indicator Public Space in Bogota D.C.

Data source: Territorial Well-being Indicator, Level socioeconomic Greater Santiago SIEDU (2017-2018), Area of squares and public parks per inhabitant.
Public space plays a fundamental role as a platform for civic action, exchange, and empowerment. Combined with green infrastructure, it can become a medium through which to improve social and environmental resilience in neighborhoods. The inhabitants of spontaneous or informal settlements in many cases build their houses and maintain them, but there is no one to build public space or to ensure its maintenance, due to its communal character. There is an opportunity to change this through interventions based on green infrastructure that, along with consolidating these common areas and improving their usability, can also improve their resilience. For example, providing a solution to the lack of pavements, not with concrete, but with permeable, porous pavements. Or including trees and productive green areas in public space.

We are proposing to look at green infrastructure and public space as media to improve the quality of life and resilience of the most vulnerable settlements with a multiscale approach that combines strategies of urban design – such as upgrading, combining, and anticipating – with the main objectives and actions that the international community has defined in order to face climate change: restoring, adapting, and mitigating. Restoring the vulnerable city after extreme climate events brings about the opportunity to upgrade and improve local conditions. These precise interventions for the improvement of public space can be thought of in terms of green infrastructure. Adapting means developing interventions that can respond to the effects of climate change. In this case, it deals with actions beyond the neighborhood scale that provide extensive ecosystem services across the metropolitan area and meanwhile contribute to the connection of precarious settlements to urban services. Mitigating means reducing GHG emissions through interventions that promote a paradigmatic change in production systems and in the use of resources (energy, transport, agriculture, etc.). In the case of precarious settlements, this means reducing the current vulnerability of informal populations and their environments but also being able to anticipate the transformation and future expansion of the settlements, based on models of climatic projections.
GREEN INFRASTRUCTURE IN THE VULNERABLE CITY: THREE TRANSVERSAL STRATEGIES

Restoring and Upgrading

A first scale of approach is the neighborhoods themselves. In other words, how can we intervene in situations of environmental risk while also improving the quality of space and life in vulnerable neighborhoods? Since 1970, many governments have started to look beyond displacement operations and have begun to focus on the improvement of neighborhoods in situ. Although in some cases, displacement is inevitable and can even have advantages for mitigating and adapting to the effects of climate change, the process can be equally disruptive for the communities. This has been the preferred strategy for the Inter-American Development Bank, which started multiple projects for the improvement of neighborhoods throughout the continent. Programs such as PROMEBA in Argentina, Favela Bairro in Brazil, and PMB in Uruguay allowed the inhabitants to conserve the buildings constructed through their personal efforts and preserve the social capital and the access to social and economic networks they had acquired over time. Their evaluations and positive results outlined new challenges and protocols and encouraged the development of more integral mechanisms that go beyond housing, to ensure the consolidation of neighborhoods and improved accessibility to the services of the city.  

Informal neighborhoods are in a state of higher risk than the formal city. Improvement interventions undertaken with communities can lead to conditions of greater future resilience, thanks to better functionality in infrastructures and the training of local inhabitants.


Repairing and building, preventing the damage caused by climate events such as storms or landslides, or responding to conditions of extreme risk can offer the opportunity for a permanent improvement of the urban quality of neighborhoods. In the same way, every intervention for the improvements of neighborhoods should include an estimate of the climate risks in the present and future, and increase their resilience. The Intergovernmental Panel on Climate Change (IPCC) is the main international body for the evaluation of climate change. Created in 1988, it provides a scientific perspective toward the current state of knowledge on climate change and its environmental and socioeconomic consequences. The IPCC recognizes the importance of improving informal settlements as a key measure for adaptation to climate change. In 2014, the fifth report highlighted that rapid urbanization and the growth of cities in developing countries had increased the quantity of very vulnerable urban communities living in informal settlements, many of which are found in areas that are exposed to extreme meteorological phenomena. Therefore, there is a need to face problems such as: i) low quality and inadequately located housing that is generally more vulnerable to extreme episodes; ii) the management of water resources; iii) the particular susceptibility of the inhabitants of informal settlements with low-income and deficient infrastructure, often located in alluvial plains or on riverbanks. The limitations of infrastructure and of the ability to plan can exacerbate the inability to resist and adapt to rapid, foreseeable changes, particularly in large cities.

In this way, we can see the importance of intervening within neighborhoods, transforming public spaces such as streets, squares, and buildings into green infrastructure that can consolidate its surroundings, offering multiple functions for the community. There are emblematic cases in the region such as the Proyecto Urbano Integral in Medellín, which has complemented the transport infrastructure network, MetroCable, with a network of public spaces for the community. The project, developed in a participatory process with the community, includes 30 infrastructure projects that improve the transit route and public equipment (education, culture, security, and employment) while also restoring the physical conditions of health in the cliff surroundings through the implementation of linear parks. Among these projects, Paseo Urbano de la Calle 107 is an intervention whose design includes a pedestrian route through a new landscape and urban corridor. The project proposes a redefinition of the public section of the street, including the improvement of existing public spaces and the construction of a park, located close to the access of the street. The objective is to strengthen the function of the neighborhood corridor, recognizing its character as a pedestrian axis, indirectly boosting business activities, for the socioeconomic development of the communities in the area. The project Plaza Estacional, developed by AGA estudio, PICO, and the Comunidad del Barrio Cañaima in the Barrio Frailes and Barrio Cañaima in Caracas, Venezuela (2010), makes the most of the need to improve the condition of hydrogeological risks in informal neighborhoods, to improve their equipment and urban quality. The project develops an operation of ground stabilization and a common patio outside the renovated housing units, in the most remote part of the neighborhood. The patio has a vegetable patch of deep-rooted plants and permaculture that transforms the square into a common patio for the development of formative and productive practices. The project is located within a site with a slope, which is vulnerable to erosion, where vegetation is used in different ways to stabilize the soil. The vegetable garden is installed within a wall that stabilizes the slope, built through the technique of permaculture, while the square is made up of porous pavement to foster the absorption of rainwater. Permaculture is a system of landscape design that simulates or imitates the patterns and relationships of natural ecosystems, as a means of generating agricultural systems or stable and sustainable landscapes. The permaculture vegetable gardens look to emulate nature, optimizing natural resources without the use of chemical products, generating microclimates of species and permitting various beneficial effects such as reducing...
the ecological footprint, restoring soil and biodiversity, creating community around working with nature, and generating organic and fresh food. These techniques work as green infrastructure and allow for public space to become a learning workshop, making the most of the local agriculture tradition.

The Tiuna el Fuerte y Lab Pro Fab Foundation takes on an unused asphalt site to create an urban park and a self-sufficient community space in the Valle de Caracas; a meeting place of culture, professional training, and sports that is rich in vegetation. The infrastructure of the park was built using low-cost and low-energy consumption technologies based on the premise of recycling, followed by an extensive research process into the neighborhood and the available materials, working closely with the local builders and artisans. For this project, recycling techniques were applied, as well as reconditioning and reprogramming of unused containers, which were grouped in modules to create the different areas of the park. Another priority was increasing the vegetal covering of the unused parking site through the incorporation of vegetal species. The Rocinha Mais Verde project in Rio de Janeiro generated a community garden for children with recycling materials and local vegetables. The project was created on an empty, unused site that had been contaminated with trash, which was cleaned and transformed into a vegetable garden. The garden

was implemented in collaboration with the local community and children, where the strategy was to make the most of the slope of the site to generate terraces that allowed for the producing and harvesting of organic food. With a similar program, the Huerta en Manguinhos constitutes a vast garden of urban organic produce, one of the largest in South America. The space is open 24 hours a day to the community in over 300 cultivable gardens. The project started with the clearing of tons of trash from the site, the elimination of the first layer of contaminated soil, and the positioning of gravel to increase drainage, followed by the construction of the walls built by bricks filled with vegetal soil. A watering system connected to the city’s water system was put in place. The garden provides fresh food for the local community all year round, alleviating the economic stress of the families and improving their nutrition. Meanwhile, it provides an improved drainage system, an environment free of trash, a social and recreational space in which to spend time, and a safe space for children. The Parque Fazendinha in São Paulo converts an area contaminated with trash into an open park for the community, a collective space for neighborhood participation. In this case, following the clearing of trash and cleaning of the site along with the local community, one of the techniques used to contain the site on a slope was unused tires that were collected from around the neighborhood, joined with rubble and cement. The Parque Trazando Sonrisas from the NGO Trazando Espacios, in

Rocinha mais Verde, Rio de Janeiro
the Escuela Agustín García Padilla (in the state of Sucre, Venezuela), is an example of a playground made through participatory design tools, recycling unused materials. Using the children’s ideas, technical plans and a building manual were produced. The manual included tools and techniques to build wooden benches and swings, tin roofs and pergolas and green roofs, games made with hoses, a mosaic mural, climbing routes, a bridge made of unused tires, and a trampoline made with rope. All of this was built with the community using recycled materials.
Adapt and Connect

All these projects are specific, in situ interventions that, in the most successful cases, are developed with and for the local communities. These transformations that react to a problem can have a long-term effect and contribute to the adapting of neighborhoods to climate change: increasing permeable surfaces, redirecting water flows, improving the physical and mental well-being of the inhabitants, and creating a feeling of belonging. The strategies of adaptation to climate change include actions that are focused on decreasing the vulnerability of people facing current climate variabilities and future changes in the climate.34 Adapting to climate change means altering our behavior, practices, systems and in some cases ways of life in order to protect our families, our economy, and our surroundings.35

If we think of how to adapt cities to climate change (for example, increasing permeable surfaces, improving drainage systems, ensuring access to water, protecting biodiversity, and promoting different lifestyles), it is necessary to establish a structural change and more ambitious projects that go beyond specific neighborhoods, looking toward integration. Improving the quality of life in informal neighborhoods in the long-term implies including them in the visions and programs for the city, improving accessibility to urban services, but also generating activities and functions in the neighborhoods themselves that can attract inhabitants from the formal city.

David Gouverneur and Oscar Grauer define these spaces as “urban connectors,” quality public spaces built in the informal city and in the formal city that can be enjoyed by inhabitants of both.36 This has been successfully implemented in many Latin American cities, among them, Rio de Janeiro, Bogotá, and Medellín, and it is being promoted in many other cities such as Buenos Aires, Santiago, Lima, and Mexico City. In the ‘90s, the project Favela Bairro in Rio de Janeiro became an important antecedent that included 200 communities and 2 million people, introducing great improvements to infrastructure, public spaces, housing, and local and

34. UNEP. Climate Change Adaptation. https://wedocs.unep.org/bitstream/handle/20.500.11822/23837/Climate_Adaption_factsheet.pdf?sequence=1&isAllowed=y
In Santiago, Chile, the Parque de la Familia has the primary objective of restoring the Mapocho riverbank in the western sector of the city, generating a calm body of water through implanting collapsible locks. The technology adopted allows for nautical activities with small, non-motorized boats such as kayaks, row boats, and small yachts. The project is located in a particularly vulnerable area in the periphery of the metropolitan area that lacks green spaces. The park and bike lanes included in the project play a crucial role in the development potential of the communities involved and the connection with central areas. The main operation of the project consisted in creating a new branch of the river, for which a great deal of earth had to be excavated and removed. The strategy was to use this excess earth to generate an artificial topography in the park and guide the river through a series of hills. The slopes of this topography and the manipulated surface were planted with native species with low-water consumption, to hold the earth together. Different tree species were also planted. Another example in which the management of water has provided an opportunity for a metropolitan public space is the Arroyo Xicoténcatl, designed by Taller Capital in a peripheral area of Tijuana. Here, the water route is requalified through the reduction of water and the creation of public and sports areas. The operation involves generating nine terraces or platforms for the development of recreational and sport activities, built with the existing backfill in the waterway. Slopes were built to contain the terraces with walls made from discarded tires, which were planted with endemic species in order to contain the earth. Two ca-


In Santiago, Chile, the Parque de la Familia [Family Park] has the primary objective of restoring the Mapocho riverbank in the western sector of the city, generating a calm body of water through implanting collapsible locks. The technology adopted allows for nautical activities with smaller, non-motorized boats such as kayaks, row boats, and small yachts. The project is located in a particularly vulnerable area in the periphery of the metropolitan area that lacks green spaces. The park and bike lanes included in the project play a crucial role in the development potential of the communities involved and the connection with central areas. The main operation of the project consisted in creating a new branch of the river, for which a great deal of earth had to be excavated and removed. The strategy was to use this excess earth to generate an artificial topography in the park and guide the river through a series of hills. The slopes of this topography and the manipulated surface were planted with native species with low-water consumption, to hold the earth together. Different tree species were also planted. Another example in which the management of water has provided an opportunity for a metropolitan public space is the Arroyo Xicoténcatl, designed by Taller Capital in a peripheral area of Tijuana. Here, the water route is requalified through the reduction of water and the creation of public and sports areas. The operation involves generating nine terraces or platforms for the development of recreational and sport activities, built with the existing backfill in the waterway. Slopes were built to contain the terraces with walls made from discarded tires, which were planted with endemic species in order to contain the earth. Two ca-

nals were also built to guide rainwater, in concrete and stone, to reduce the speed of water flow. Areas for sports, playgrounds, and meeting spaces were incorporated. In the Represo Colosio in Nogales, Mexico, a body of water was redesigned with a public space next to it, to avoid the risk of flooding in an area of informal settlements. The ecological design strategies adopted were based on the containment of the borders of the water bodies and the consolidation of the dam curtain; the definition of the space for water flow; and floodable areas that can receive rainwater in rainy periods, to be used for sports and leisure during dry periods. A perimeter circuit and a bridge were also created to facilitate mobility and evacuation of the inhabitants in case of emergencies. In order to materialize these strategies, local construction systems and materials were used: containment walls with local stone, pavement made from compacted earth and polished concrete, squares with local stone, and gardens with cactus plants from the area.

Other projects focus on the construction of network and work systems, with or for institutions to improve the integration of neighborhoods into the formal city. Specialized in the design of open spaces in informal neighborhoods, Enlace Arquitectura, a firm from Caracas, has created a parallel agency, the Fundación Enlace Arquitectura, to promote the investment of local and metropolitan governments in public space. The project Sembrando Ciudad – La Palomera proposes a series of interventions of recycling public space in interstitial and contaminated public spaces in order to improve the quality of life in neighborhoods, but also connecting them to the formal city. In the Plaza de la Cruz project, the community selected a clandestine garbage dump and transformed it into a new and dynamic public space that is also a lookout point onto the city. The project motivated the creation of a new system of waste management that was organized along with the council and the community in order to guarantee that the space would not be used to dump waste. The new waste collection system allows for the elimination of waste containers in the entrances of the

An emblematic case is the ecological park in the Moravia neighborhood that transformed one of the main dumping grounds in Medellín into an urban park that is rich in vegetation, walking paths, community gardens, and cultural activities for the local community. This case is an example of the reconstruction and restoration of a highly degraded territory through the participation and concertation of the inhabitants, the study and design of technologies for environmental recovery, as well as urban and landscape studies. From the techno-environmental element, an artificial hill that had been created by the accumulation of waste over the course of several decades was consolidated and decontaminated, and a system of water management was proposed through natural systems of purification, materialized in the community gardens and the built wetlands. The former consist of planted or buffer strips that generate an environmental solution but also have a social and educative function for the residents who previously lived in the dumping ground. The wetlands purify through underground perforated tubes.


neighborhood, which constitutes an important improvement in the public health of the community. Today there are seven new routes of door-to-door waste collection in La Palomera. The Caminos de la Villa project in Buenos Aires promoted the recognition and integration of informal settlements [villas] through the participative construction of detailed online maps of the villas, which do not appear in the official maps of Buenos Aires. The design and implementation process consisted of the following stages: neighborhood coordination; mapping all of the internal passages through GPS coordinates along with the inhabitants of the neighborhood and validation of the cartographic data with the neighbors; publication of the maps; the design of an interactive web platform for the use of the maps; a presentation of the platform in the neighborhoods; and the constant updating of the information. This mapping process and continuous updating of the information is fundamental for the integration of the neighborhoods and the projection of green infrastructure.

La Palomera, Caracas

Morro de Moravia ecological park, Medellín
Mitigate and Anticipate

Finally, both to address climate change and to develop more sustainable cities, it’s necessary to intervene in the causes. Climate change mitigation strategies include actions focused on reducing the sources of greenhouse gases and increasing carbon sinks, to avoid extreme warming of the planet. This means imagining new ecologies, economies, and societies to anticipate future conditions. In this way, it is important to think of informal settlements as a developing reality, anticipating transformations and mitigating eventual risks.

In recent decades, many cities in Latin America and their informal neighborhoods have been in the process of consolidation. However, as we saw in the previous pages, new mitigation routes at a national and international level, along with demographic growth, keep driving the expansion of informal neighborhoods. Different organizations and authors from around the world have written extensively about the consequences of this demographic explosion and the nature of informal occupation. However, little has been done in terms of imagining how to effectively deal with the consequences of these demographic pressures and how to face the increasing population in cities, predominantly the informal one. According to data from the United Nations (2018), the proportion of the urban population living in marginal neighborhoods around the world decreased by 20% between 2000 and 2014 (28% to 23% of the total). This positive tendency has recently reversed, and the proportion increased to 23.5% in 2018. The absolute number of people living in marginal neighborhoods or informal settlements increased to more than 1 billion, with 80% attributed to three regions: East and Southeast Asia (370 million), Sub-Saharan Africa (238 million) and Central and South Asia (277 million). The other regions have 199 million people. In 2018, 23% of the population of Latin America and the Caribbean did not have access to waste collection (increasing from 20% in 2001-2010).47


Various authors, such as Elisa Silva and David Gouverneur,46 state that housing is not the main problem. Although the resources of self-built housing can vary greatly between countries and within the same contexts, people have the ability to gradually build their own housing. The central problem is rather the lack of appropriate habitats, ones in which these refugees would have a greater opportunity of evolving as part of a healthy and robust system. The informal settlements that are configuring the urban landscape of cities in many developing countries are far from being successful forms of land occupation. This can be seen through a range of indicators: quality of life, autonomy from global markets, dependence on the formal city, environmental impact, resources, consumption, social mobility, governance, and happiness, just to mention a few. In these settlements, basic services such as water, treatment of residual water, and the elimination of waste are inexistent or very poor. Here, we rarely find public spaces and services, and economically these areas are highly dependent on the formal city. In addition, the residents do not have access to education or health services (basic human rights), economic opportunities are scarce, and the rate of violence and delinquency can be surprisingly high.

According to Gouverneur, the challenge of design in marginal communities is guiding the growth of settlements before and while new territories are being occupied, in a preventive way, introducing creative, strategic, and design movements during the first phases of occupation, while the evolution in time is visualized.43 Directed interventions can become components that are as successful as complex and wider systems, and can improve the living conditions for hundreds of millions of people in these newly developing cities. Informal settlements cannot be considered a marginal urban condition, but rather the main current in dynamic forms of complex urban ecologies that are shaping highly populated cities in the developing world. It is possible to make the most of this logic and its internal forces and foster a better performance of the system through frameworks that can help informal settlements manage systems of society, water, food production, mobility, etc. Gouverneur calls these “informal armatures”45.
Climate change mitigation strategies imply imagining new ecologies, economies, and societies to anticipate future conditions. In this way, it is important to think of informal settlements as a developing reality, anticipating transformations and mitigating eventual risks.

The improvement of informal settlements is an important task, but it is also complicated, slow, and expensive. It can provoke substantial changes in the functioning of informal neighborhoods, although it has less impact on regional scales. One reason for the difficulty of this focus is the level of consolidation and rigidity of the urban fabric in most of these settlements. To improve connectivity, provide infrastructure and community services, or relocate residents from inappropriate locations (due to geological instability, risk of flooding, locations under electrical lines or over gas networks, etc.), it is necessary to have space. Space that is generally unavailable in the proximity of very dense urban conglomerates. To face these challenges and anticipate future transformations, defense strategies can be defined that, in terms of a metropolitan and regional scale, can guide the location and the transformation of the predominantly informal city that operates on different scales. These strategies consist mainly of green infrastructure that incorporates different services and protects land from future building, connecting developing areas to services and between them. These can be very malleable and work with very different spatial restrictions. The main task is to provide the conditions that will transform these areas into new developing cities, instead of submissive, marginal components of the formal city and the globalized market. These can be understood as “hybrid, dynamic urban ecologies that can become the dominant form and best occupation of land in the developing world.”
Most investigations about informal (or postformal) settlements are centered on retroactive strategies that improve the existing conditions, similar to a "small-scale urban acupuncture." However, there has been little emphasis on preventive strategies that approach future growth. Landscape interventions on public space and green infrastructure, as well as multiple environmental, economic, and social advantages, allow for flexibility and continuous reorganization. Projects like the Parque Ecológico del Lago Texcoco de Iñaki Echeverría preserve a great lacustrine reserve in the periphery of the city. The Parque Ecológico reactivates the hydrological processes affected by peripheral urbanism through the introduction of some areas of regulation and reforestation, reintroducing species of the ecosystem that have almost disappeared. Along with the remedy process, there are new areas for recreational activities with areas for sports, structures for ecotourism, museums, and research centers, making the most of a new renewable energy network that feeds the whole system. The project also includes a series of productive landscapes for local agriculture. In its first implementation phase, there is the recovery of bodies of water, the construction of nursery gardens to cultivate local species and achieve the specific forestation of the area, as well as improving dirt roads.\(^\text{54}\) In Bogotá, the Corredor Ecológico de los Cerros Orientales, designed by Diana Wiesner, transforms the borders of the city into an ecological corridor and a productive urban park, benefitting the adjacent informal communities and the entire metropolitan city. The project and territorial ordinance model, created in 2006, looks to restore biodiversity as a social development strategy and for the territorial appropriation by the communities. This implicates the creation of the largest ecological and recreational corridor for public use in the city. The model is composed of an environmental and biosphere strategy that looks to increase ecological connectivity; a sociocultural strategy that looks toward social development and participatory planning; and a spatial strategy that looks to physically demarcate the city limits with the reserve. In 2015, three hectares of Natural Reserves were made into a pilot project for the management of the Cerros Orientales.


\(^{54}\) The project has received criticism for being a large-scale design that was proposed without consulting the affected communities. The implementation process was delayed for a number of years and resumed at the start of 2020 with the construction of the first section.
The Rutas Naturbanas project looks to connect five areas in San José, Costa Rica, through nature. The 25 km route is designed as a green infrastructure that contributes to the conservation of ecosystems and the creation of interurban biological corridors, cleanliness and protection from rivers, as well as new areas for recreation and natural spaces for slow mobility, the reduction of the carbon footprint, connection between neighborhoods and urban centers, and increased safety for pedestrians or cyclists in marginal areas, including informal settlements and the urban center. The first 600 m have been built and the first kilometer is due to start construction in 2021. The project aims to regenerate the vegetal and forest layer in the banks of the rivers through a categorization and selection of vegetation, defining areas for regeneration, reforestation, and forest stabilization with native and pioneer species that restore the environment. An exhaustive study of the river sections and their differential qualities was also undertaken for the construction of the route, guaranteeing points of access and connection with surrounding areas. Mapocho 42K in Santiago de Chile also looks to build a green network, in this case a cycle route, at a metropolitan scale. The main objective is to achieve social and territorial connectivity, reducing the breadth of urban inequality through a metropolitan-scale route that includes landscape and geographical attributes in Santiago. Following the course of the river, this public route follows a vertebral spine in the East-West direction, defining a green and continuous corridor that connects existing and potential green spaces that are located along the river; in this way, it manages to connect these areas that were previously fragmented or inaccessible to other nearby parks. The strategy of the project is to consolidate this geographic and ecological network, creating a system of parks and integrated public spaces through water.
Anticipating the transformation of the metropolitan city and mitigating future impacts are the objectives of the BIO 2030 plan for Medellín. The principal aim of BIO 2030 is to establish occupation criteria for the Valley of Aburrá that can influence the current growth tendency toward a more sustainable model of occupation. These criteria are articulated following two thematic macro areas: environment, landscape, and public space; and mobility and transport. Following these categories, strategic projects are being undertaken in different parts of the river and its surroundings to prioritize and direct territorial actions as pioneers of a new model of occupation that is more sustainable and socially equitable. The strategies to control urban growth along the riverbanks are particularly relevant, as they include measures to contain expansion, reduce risk, restore ecological integrity, and consolidate viable settlements. This includes a series of proposals to work in large areas occupied by informal settlements with adverse geographic conditions. The Sistema de Refuncionalización y Recuperación del Arbolado Urbano (System of refunctionalization and recovering of the urban tree canopy), formulated by the Consejo de Coordinación de Políticas Públicas for the metropolitan area of Mendoza, is implementing a metropolitan, integrated system of institutional strengthening and improvement of infrastructure, for forestation and existing irrigation. This is oriented toward the restoring of public urban trees, under sustainable development guides and according to models of modern arboriculture and silviculture. The project is structured into five components that deal with the problem of urban forests in an integral way: a Mesa de Gestión de Arborización (management meetings for public trees); a system for mapping, information and management of urban trees; the refunctionalization of nursery gardens to guarantee the provision of trees; the provision of equipment and machinery for councils for the forestation process; and the permeabilization of ditches and improvement of irrigation infrastructure to achieve an improved management of water.
Green infrastructures and nature-based solutions have the ability to restore part of the benefits that natural environment provides, in the form of ecosystem services. There are a multitude of benefits that nature can provide to society; benefits that have been reduced by the effects of climate change but that are crucial for the quality of public spaces in vulnerable neighborhoods and for generating greater resilience in the face of new changes. In this way, green infrastructure provides on the one hand an opportunity to reestablish these services and, on the other hand, provides quality infrastructure that can be implemented by local entities at a reduced cost.
Green infrastructure offers quality infrastructure for vulnerable populations at a reduced cost and with a feasible implementation using local means.

The interventions of the consolidation of lands, as undertaken by AGA studio or ETSAM in Caracas and Medellin, provide neighborhoods with better adaptation strategies to extreme climate events and also work to absorb carbon. Using local techniques and existing materials in the neighborhood for the construction of Parque Tiuna el Fuerte contributed to the recycling of waste and limited the usage of energy and economic resources. The reconversion of dumping grounds in the Parque Fazendinha and the Barrio Moravia occupy techniques of environmental requalification, such as strips of vegetation and wetlands to clean the ground and water. They also have a social and educational function and contribute to the improvement of the future use of natural resources. The Palomera project was conceived with the intention of creating a new public space with functions for the community and vegetation to improve the micro-climate. The opportunity to do this is presented in the recycling of a dumping ground, reimagining the waste collection system in a more efficient and sustainable way, mitigating future impacts. The Arroyo Xicoténcatl and Represo Colosio parks, respectively, requalify the river and a body of water and redesign a public space with techniques based on nature in order to function at a time of drought as well as rainfall. With this, the neighborhoods are adapted to the most extreme climatic seasons, and there are resilient parks for the short and long term. Analogously, urban parks conceived to generate new spaces for recreation in low-income areas, such as the Parque de la Familia and the Parque Biblioteca España, can play a fundamental role in the protection of an inhabited area, in the case of landslides, tsunamis, or hurricanes, as well as reducing the contamination of air and lowering temperatures. New metropolitan routes such as the Mapocho 42K or Rutas Naturbanas have been conceived to offer alternative systems of mobility and offer incredible socioenvironmental benefits for the neighborhoods they traverse. They can also contribute to the filtering of water, working as a buffer along with the rivers they accompany, adapting them to extreme climate events such as landslides and frequent rainfall.
These technical and design solutions show how green infrastructure is part of the alternatives needed to combat climate change and the inequality of opportunities. They also make up a series of established and successfully proven techniques in different parts of Latin America and the world. Nowadays, the techniques and methodologies available for the design and implementation of green infrastructure are extensive, diverse, widely accessible, and gathered in manuals. The examples and case studies are numerous. However, in spite of their abundance, the manuals of green infrastructure are mainly directed toward formal urban surroundings and consider certain urban standards as a basis for the implementation of available techniques.

With the ambition of compiling and revising existing technical documents in the form of manuals that have been published in different countries in the past decade and that have provided tools for the design of green infrastructure in public spaces. With the intention of highlighting a series of techniques to be used in informal neighborhoods, we selected ten manuals of green infrastructure, including those more used and quoted in Europe, Latin America, and North America, and some cases of manuals focused on specific subjects that can be useful for addressing conditions of informal settlements.56

In Latin America, the Manual de Lineamientos de Diseño de Infraestructura Verde para Municipios Mexicanos (Mexico, 2017), for example, is notable for its breadth, completeness, and organization in relation to the different scales of intervention. The Manual de Drenaje Urbano by the Ministry of Public Works in Chile (Chile, 2013) presents in a complete way the macrozones or regions based on the knowledge of the physical media (climate, geomorphology, hydrology, ground types, etc.), relating to techniques that are better for each zone. Presenting a particular focus on the techniques for urban drainage, and with an additional chapter on vegetation, explaining types of vegetation in relation to their use, The SUDS Manual (2015), the manual for urban drainage techniques in the UK, is very detailed in terms of the Sustainable Drainage System techniques, in relation to cost and benefit and maintenance levels, its relation to climate change mitigation, and a focus on the design for different locations. The definition of the focus is interesting – design for quantity/quality of water, user comfort and biodiversity – with particular attention to social improvements through the design of SUDS. Another manual that is a reference for urban designers and city officials is the City of Philadelphia Green Streets Design Manual (Philadelphia, 2014), which is focused on the specific context of Philadelphia. It includes comparisons between techniques used and others being developed in the city, and particular attention is given to the graphic representations (axonometric drawings and diagrams) aimed at the community’s comprehension. The Guía de la Infraestructura Verde Municipal (Spain, 2019) is remarkable for its multiscale, socioeconomic focus and for the importance given to the dependence between green infrastructure and human well-being, as well as to peri-urban green infrastructure that can be related to infrastructure in informal neighborhoods. This last manual references the Stormwater Management Design Manual (New York, 2015), which is chosen mainly for its focus on the impact of urbanization on previously natural areas, and for its description of both local techniques and large-scale strategies. Related to the peri-urban green infrastructure of the Spanish guide, a search of international manuals was undertaken, but with a focus on green infrastructure in communities with a deficit of grey and rural infrastructure. From this exploration, the Canadian manual, A Green Infrastructure Guide for Small Cities, Towns, and Rural Communities (Canada, 2017) for low-cost and easily implementable, low-impact development, was looked at. Other manuals, such as Low Impact Development and Green Infrastructure Guidance Manual (Arizona, USA, 2015); Washington, Low Impact Development, Stormwater Management Planning and Design Guide (Canada, 2010), finally, we reviewed two recent publications by the International Development Bank, Informe de Infraestructuras Verdes Urbanas (IDB, 2017) and the guide, Increasing Infrastructure Resilience with Nature-Based Solutions (IDB, 2020).
development. Here, we found the manuals, *Low Impact Development and Green Infrastructure Guidance Manual* (Arizona, 2015), *Low Impact Development, Technical Guidance Manual for Puget Sound* (Washington, 2012), and *Low Impact Development Stormwater Management Planning and Design Guide* (Canada, 2010). We also reviewed two guides that were recently published by the Inter-American Development Bank. The *Informe Infraestructuras Verdes Urbanas* (2017) is focused on case studies and techniques adopted, highlighting aspects of multiple scales, comparing costs of different projects, always with a focus on the impact of urbanization on the risks of climate change. The *manual Increasing Infrastructure Resilience with Nature Based Solutions* (2020) is highlighted for its focus, case studies, and description of the stages of projects, defining a guide to the implementation of projects based on nature.

In terms of the general subjects of the manuals and green infrastructure projects mentioned, we can highlight the focus on European, North American, Canadian, and Australian contexts. In general, the evaluated manuals have deficiencies in acknowledging the risks and impacts of climate change. Many of these do not consider legal and ordinance aspects, actors, and the design and construction processes, which have a very significant impact on the feasibility of the projects. The socioeconomic levels and relationship to informality are still absent in most of them. The costs and benefits only have a partial presence, and not many include case studies or pilot projects. The techniques, both at a medium urban scale, and at a local scale, and the context of green infrastructure with different levels of definition, are common in the majority of the manuals. Although part of this knowledge and experience can be useful, many of the conditions are not applicable to Latin American contexts for different reasons. Both the Latin American manuals that we analyzed, from Chile and Mexico, are very complete, particularly in the detail of the bioclimatic zones of Chile and the technical descriptions. However, they do not include the perspective of informality, nor the adapting of techniques to different socioeconomic contexts. They do not include much information about the actors involved in the process of implementing green infrastructure projects either, and they do not extensively consider the risks and impact of climate change. Concerning informality, the Mexican manual mentions low-cost techniques, and the Spanish manual describes low-tech, local techniques, but they do not specifically reference informality.

For each manual, we reviewed the attention dedicated to each thematic section, assigning a score from 1% to 100%, and we calculated the average percentages that would help us understand the general focuses. All the manuals had a good average in terms of subject focus (72%), techniques and urban strategies (58%), and local strategies (57%). However, as they do not deal with the particular conditions of informality (10%), they lose relevance in this sense. Green infrastructure, by nature, should respond to local bioclimatic conditions. For its implementation and maintenance, it needs to involve all the relevant actors, including the local community. These actors include but are not limited to: aspects concerning material subcontractors; selection of nature plan species that can prosper in those surroundings and be linked to local cultures and lifestyles; use and implementation of local knowledge (techniques and abilities) to implement the infrastructure, responding to each informal settlement. Most of the manuals deal with the subject of actors in marginal terms (27%), and are not focused on legal, ordinance, or financial aspects (36%). In order to assure successful implementation of green infrastructure, it is necessary to establish a methodology with guides and instructions that indicate these local conditions. Case studies and pilot projects also assume a minor relevance in the analyzed manuals (24%), although we think they would be useful in highlighting processes, techniques, and benefits; it would be even more important to include case studies and pilots in informal settlements, which are almost inexistant in the current literature.

In the bibliographical review of the manuals, we have confirmed the lack of and necessity for the development of material that is specific to informal settlements, as, although all the reviewed documents are very interesting and useful, there is no material specifically dedicated to the most vulnerable contexts.

Hoping to at least partially fill this void, we are developing a manual for the design of green infrastructure for informal neighborhoods, including a revisiting of the main techniques that are easily applicable and have low...
construction and maintenance costs; ordinance and financial aspects; actors and specific processes in informal contexts; catalogues of local techniques, materials, and species; and some examples of case studies and pilot projects that apply this knowledge on site. In order to show a model of how this manual can be organized, we developed a specific one for the province of Corrientes, Argentina. This manual presents scenarios, techniques, and a prototype, which is to say a series of solutions for and processes of implementation and maintenance, based on existing conditions and considering the neighborhood of Doctor Montaña, an informal settlement in the city of Corrientes. The basic sections, for example, respond to the existing dimensions and physical conditions in Doctor Montaña, just as realized climatological conditions are measured in order demonstrate potential benefits. We also include catalogues of local techniques and materials, such as crushed brick and wood, which are locally produced, and native vegetal species of the bioclimatic region of Corrientes.

The emphasis on the manual that we developed for the case study of Corrientes is on representing public spaces in a transversal way. This is to say, it not only includes infrastructure and environmental aspects (the heat island effect, carbon absorption, protection from floods), but it also attempts to represent the cohesion of the community and its quality of life, to mitigate the different forms of territorial vulnerability through the implementation of green infrastructure. We adopt a multisectoral and multifunctional perspective, whose benefits and impacts should be valued on a physical but also economic, social, and institutional level. In order to achieve the integration of techniques of green infrastructure into informal surroundings, we collected the most relevant techniques for this context and connected them to sections of green infrastructure, potentially implementable in low-income neighborhoods. The catalogues are divided into systems of infiltration, conduction, transport, and gathering. They include the benefits and feasibility for their adaptation to different contexts.

Similarly, the catalogues of tree vegetation and materials only include local species, and they are specified according to the design and implementation potential with respect to the relative space of the low-income neighborhoods. The success of the manual depends on the decisions made with respect to the Risk Atlas previously presented in this document. If the Manual specifies the guides and instructions for developing the techniques of green infrastructure in specific neighborhoods, the Atlas ensures the understanding that the low-income neighborhood is not isolated, it is interdependent with other landscapes and territories at different scales (local, provincial, regional, national, and even global). The decisions made at other scales in the Risk Atlas will have an impact on the implementation of the Manual. Therefore, it is important to see the manual as part of a constant dialogue with other scales, as well as an instrument for improving the resilience of neighborhoods to climate change, connecting them and integrating them with urban areas, and anticipating future territorial transformations.
Scenarios: Climate Conditions and Benefits of Green Infrastructure

First of all, we defined a series of scenarios or design projects for public space, based on ecological principles. Each scenario is designed by taking into consideration the climate and the urban space typical of settlements in Corrientes. It is conceived to function both in rainy and dry seasons. In Map 42, Corrientes and its hydrological system is located, and to the right there is an aerial view of the Doctor Montaña neighborhood, which has been considered due to its typical sections and the scenarios that follow. The sections, Graph 26 and those following, show the impact of high temperatures such as the albedo effect and rainfall, and the benefits of green infrastructure. A first scenario represents the conditions present in public space with traditional infrastructure in dry seasons. In Graph 26, the advantages and disadvantages are compared in relation to green infrastructure. Graphically, traditional aspects are included, such as asphalt pavements, non-permeable surfaces, rainwater drainage through tubes, mixed with grey and black water, and minimal or nonexistent green areas and routes for alternative transportation. Typically, this type of infrastructure contributes to the exacerbation of high temperatures and contaminants in spaces, contributing to the deterioration of health of the community in the summer months. There is also an increase in the generation of the effect of heat islands. This discourages the use of streets and public space for social meetings, prioritizing private mobility and mainly cars.
This section represents the conditions of the public space equipped with traditional infrastructure in the dry season. A) We can compare the advantages and disadvantages it has regarding green infrastructure. Graphically they include traditional aspects such as asphalt pavements, non-permeable surfaces, rainwater drained through pipes and mixed with sewage (black and/or gray) and minimal spaces or non-existent green areas, and for alternative transportation.

Typically this type of infrastructure contributes to the exacerbation of high temperatures and pollutants, and to the deterioration of the community’s health in the summer. In addition, it increases generation of the heat island effect and discourages suitable spaces for social meetings, prioritizing the space for private mobility in the form of cars.
During the rainy season, traditional infrastructure is designed to evacuate rainwater through tubes, which at times of extreme events don’t have the capacity to contain or manage large quantities of water that threaten the city. The lack of vegetation and its fragmentation decreases the ability of water retention of the ground and its filtration. This type of traditional infrastructure exacerbates the possibility of catastrophes in urban settings, such as flooding, due to the poor ability of retention and filtration. These events saturate the tubes and leave residual materials that in the long term diminish drainage capacity. They also contribute to ground erosion and the elimination of the little existing vegetation, razing the vegetation and accelerating the degrading of surfaces and the use of public spaces. **Graph 27** shows the advantages that the same green infrastructure can offer in rainy seasons, canalizing and absorbing the water.

**Graph 28** is focused on the role that green infrastructure can play in the improvement of the climate, both in reality and as it is perceived. During the dry season, green infrastructure improves air quality and temperature, diminishing the effect of heat islands. Its capacity to retain humidity in the roots contributes to the generation of microclimates and the reduction of air-conditioning in homes. The shade provided creates areas for social meetings. The coolest surfaces of permeable pavements are also more attractive for sports and sustainable transport activities such as bicycles. All this has effects on the health and well-being of the community, as well as having economic benefits. The albedo effect, or reflection of solar radiation, has a huge effect on the heat island effect. Dark materials such as asphalt absorb heat that is gradually emitted during the night, worsening the effects of extreme heat or cold, increasing energy consumption and the production of ozone. Black asphalt can have albedos of 0.05-0.12. Fresh, permeable pavements can reach up to 0.35. A difference of albedo of 0.30 can result in differences of 10 degrees centigrade on the material surface. For trees, an albedo of 0.2 is used, and for rain gardens and hedges, 0.25. For the contribution of vegetation and decreasing of temperatures, the reduction of the effect of heat islands is generated in the use of materials with higher albedo. For example, tree foliage can decrease the heat island effect up to 6 degrees centigrade in temperature.

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**Note:**

In the rainy season, the traditional infrastructure is designed to evacuate rainwater through pipes which, during extreme events, do not have the ability to contain or manage large amounts of water to the detriment of the community. The lack of vegetation and its fragmentation decreases the water holding capacity for groundwater and its filtration.

This type of traditional infrastructure exacerbates the possibility of catastrophes in urban environments such as floods, due to its low retention and filtration capacity. These types of events also saturate pipes and leave material waste that, in the long term, end up diminishing their capacities to drain. In addition, they contribute to soil erosion and eliminate little vegetation that exists, destroying the vegetation and accelerating the degradation of surfaces and the use of public space.
In dry seasons, the Green Infrastructure improves the quality of the air and its temperature, reducing the heat island effect. Its ability to retain moisture in the roots contributes to the generation of microclimates and saves air conditioning in the households. Shaded spaces create social meeting areas. The cooler permeable pavement surfaces are more attractive for sports activities and low-waste transport such as bicycles. All this is reverberated in the health and well-being of the community, in addition to the savings and economic benefits that it entails. The albedo effect, or reflection of solar radiation, has a great influence on the heat island effect. Dark materials such as asphalt absorb heat that is generally emitted overnight, worsening the effects of extreme heat or cold, increasing energy consumption and the production of ozone. Black asphalt can have albedos of 0.05–0.12.

The fresh, permeable pavements can reach up to 0.35 (Akbari, 2007). An albedo difference of 0.30 can result in differences of 10 degrees Celsius on the surface of the material. For trees an albedo of 0.20 is used, and 0.25 is used for rain gardens and shrubs. For the economic impact of the decrease of the temperature, the reduction of the heat island effect is assumed by the use of materials with higher albedos. According to Gartland, the heat island effect under tree-canopies can increase up to 6 degrees Celsius. These values are used to measure the impact on reducing the heat island effect.

Data source:
As we can see in Graph 29, in rainy seasons, green infrastructure reduces flooding through ditches, canalizations, and areas for the accumulation of water. Vegetation increases the ground’s capacity for absorption and recharges the aquifers. This also filters the water, reducing the contaminants and diseases that can be transmitted through stagnant unclean water. In the case of informal settlements on slopes, the vegetation stabilizes the grounds in order to prevent landslides. Cellular pavements contribute to the filtration of water. The benefits are not only seen at a neighborhood scale, but also at the scale of the city; these measures reduce the pressure in urban drainage systems and increase, through recycling, the availability and quality of water in aquifers. The implementation of green infrastructure in informal settlements integrates them into hydrological systems in immediate urban and natural settings, contributing to their health. For example, green infrastructure discharges clean and filtered water downstream, and retains considerable volumes of water in rainy seasons, contributing to the controlling of floods and allowing for water storage for other uses. The vegetation corridors allow its connection to other green areas in the city, increasing biodiversity and health in ecosystems, relating the community with nature and socio-environmental resilience. These corridors also increase carbon absorption both through vegetation and more fertile ground. Graph 30 shows in detail some of the main technical solutions that allow for the management of water in rainy seasons: green ditches, rain gardens, cellular pavements, streams, and canals.

The implementation of green infrastructure in informal settlements integrates them into hydrological systems in immediate urban and natural settings, contributing to their health.
In rainy seasons, the Green Infrastructure reduces the flooding via ditches, pipes and spaces of water accumulation. Moreover, the vegetation increases the soil’s capacity for absorption and recharge of the aquifers. This filters the water, reducing pollutants and diseases that can be transmitted through dirty water stagnation. Cellular pavements contribute to water filtration. The benefits are not only seen at the neighborhood level, but also on the city scale. These measures reduce pressure on urban drainage systems and by recycling, increase availability and quality of water. (cont. Page 303)

2) The implementation of green infrastructure in popular neighborhoods integrates them into the hydrological systems of immediate urban and natural environments, contributing to a healthier infrastructure with minimal impact on the environment. For example, green infrastructure reduces flooding, filters downstream, and retains considerable volumes of water that, in rainy seasons, help prevent flooding and store the liquid for other uses. The vegetation corridors allow its connection with other green areas of the city increasing biodiversity, ecosystem health, community contact with nature and socio-environmental resilience. In addition, it increases absorption of carbon both through vegetation as well as the most fertile soil.
The albedo effect, or reflection of solar radiation, has a great influence on the heat island effect. Dark materials such as asphalt absorb heat that is emitted during the night, worsening the effects of extreme heat or cold, increasing energy consumption, and ozone production. Black asphalt can have albedos of 0.05–0.12. Fresh, permeable pavements can reach up to 0.35 (Akbari, 2007). An albedo difference of 0.10 can result in differences of 10 degrees centigrade on material surfaces. Trees use an albedo of 0.20 and rain gardens and shrubs use 0.25. (cont. Page 2) For the contribution of vegetation in the decrease in temperature, the reduction of heat island effect is assumed, for use of materials, with higher albedo. According to Akbari, H. (2007). Opportunities for saving energy and improving air quality in Urban Heat Islands. Gartland, L. (2008). Heat Islands. Earthscan.
Green infrastructure plays an important role in the passive cooling of public space, allowing for social and community activities in dry and hot seasons. During rainy periods, these spaces can serve temporally to accumulate water and prevent flooding.

The selection of the species of native vegetation is vital in order to build climatic resilience and generate continuities with existing ecological areas, as well as making the most of the specific characteristics (consumption of water, feeding habitat for local fauna, adaptation to local climate, etc.), which depend on and respond directly to the local geographical surroundings. Graph 33 shows some of the techniques that allow this versatility in uses such as filtrating strips, retention ponds, and porous and cellular pavements.
The Green Infrastructure has the ability to integrate with other programs and activities in the neighborhoods and is able to be implemented in coordination with spatial allocations for recreation, schools, health, and education institutions, among others. These landscape improvements and access to recreational spaces generate greater social cohesion, training and environmental commitment. Green Infrastructure plays an important role in passive acclimatization of these spaces allowing social and communal activities during the dry season.

These spaces can be built with local materials and techniques in order to involve the community in their creation and subsequent maintenance. The selection of native vegetation species to build climate resilience and generate continuities with ecological areas in addition to taking advantage of its specific features (water consumption, habitat food for local fauna, adaptation to local climate, etc.) that depend on and respond directly to the local geographic environment.
During rainy events, these spaces can temporarily serve to accumulate water and prevent flooding. The recharge of aquifers stores that accumulation for the dry seasons where the increased capacity of soil moisture retention contributes to the generation of microclimate. Temporary retention ponds help relieve pressure on the overall system of the town. This translates into economic savings in disaster management and increases socio-climatic resilience.

The vegetation in these spaces can also serve as a generator of locally sourced materials and cost reduction. Through the integration of gardens or small orchards in urban areas, contributing to the educational aspects and health benefits in the Green Infrastructure.
Vegetation 1.5 m
Vegetation 2.5 m
Vegetation 2.5 m
Waiting room 3.0 m
Vegetation 1.5 m
Seated steps 2.5 m
Seated steps 2.5 m
Pedestrians 2.0 m
Play area 9.5 m

**Graph 33**
**Green Infrastructure Details Section**
**Playground Spaces (Rainy Season)**

**Filter Strips**
- Grass
- Ap Horizon
- E Horizon
- Btss
- Big 1
- Big 2

**Retention Ponds**
- Ap Horizon
- E Horizon
- Btss
- Big 1
- Big 2

**Porous Pavements**
- Perm roll folder
- Sand bed
- Top granular filter (base)
- Porous material (subbase)
- Permeable geotextile sheet
- Btss

**Cellular Pavements**
- Layer of soil
- Permeable pavers
- Sand bed
- Top granular filter
- Porous material
- Permeable geotextile sheet
- Btss

Data source:
Just as recreational spaces can improve the health of ecosystems, urban landscapes such as forests and wetlands can become recreational areas accessible to the community. This appropriation has major social benefits and affects the maintenance of these spaces.

Wetlands play a crucial role in the increasing of biodiversity, resilience to climate change, and above all, absorption of carbon, since along with forests, they are the ecosystems that most absorb emissions. As well as this, they become key points for the dissemination of environmental knowledge and consciousness. As shown in Graph 34 and 35, wetlands have the ability to treat and filter water through phytoremediation for its recycling and later use, or to recharge the aquifer with clean water, resulting in savings on the treatment of water, both in rainy and dry seasons. These spaces can serve both as attractive landscapes for the neighborhood and to generate wood or medicinal plant resources. It is therefore important to connect them to adjacent spaces through landscape solutions that can support different activities, respecting the ecosystem of the wetland. These can also play a key role, not only in low-income neighborhoods but also in urban surroundings, as they can be connectors of larger hydric systems, with which the ecosystem’s health, connectivity, and therefore resilience are improved. Graph 36 shows the detail of the functioning of the wetland and some technical solutions that can be considered to improve the wetland and its surroundings.

Wetlands play a crucial role in the increasing of biodiversity, resilience to climate change, and above all, absorption of carbon, since along with forests, they are the ecosystems that most absorb emissions.
Just as recreational spaces can improve health ecosystems, urban landscapes - such as forests and wetlands - can be converted into accessible recreational areas for the community. This appropriation has enormous social benefits as well as benefits in the care and maintenance of these spaces. Wetlands play a crucial role in increasing biodiversity resilience to climate change, and especially in carbon absorption, since it is one of the ecosystems that most fulfills that function. These spaces can also serve as attractive landscaping for the neighborhood or generate wood resources or medicinal plants. These spaces can also serve as attractive landscaping for the neighborhood or generate wood resources or medicinal plants.
Wetlands can play a key role not only in the low-income neighborhoods, but also in urban settings, as they can be connectors of larger water systems, improving the ecosystem’s health, connectivity, and resilience. Wetlands have the ability to treat and filter water through phytoremediation for recycling and subsequent use or to recharge the aquifer with clean water. These spaces can also serve as attractive landscaping for the neighborhood or generate wood resources or medicinal plants.
GREEN INFRASTRUCTURE DETAILS SECTION

ECOSYSTEM SPACES (RAINY SEASON)

Data source:

Vegetation
- 1.5 m

Play area
- 5.0 m

Vegetation
- 1.5 m

Pedestrians
- 3.0 m

Elevated view
- 9.0 m

Wetland

Cellular pavements

Green slopes

Water purifying plants

Clean air

Clean water

Improved visual quality

Increase in biodiversity

Secure recharge of aquifer

Reduced flooding risk

Large public spaces for recreation and sports

Connection to a network of additional hydrology

Layer of soil

Permeable pavers

Sand seal

Top granular filter

Porous material

Permeable geotextile

Ap Horizon

E Horizon

Btg 1

Btg 2

Filter

Clean air

Clean water

EcoLOGICAL DESIGN

IDB
Catalogues: Local Techniques, Typologies, Materials, and Native Species

In order to build a catalogue of ecological design strategies, we brought together the most relevant techniques of sustainable urban drainage and nature-based solutions that are applicable in informal settlements. We proposed a series of architecture typologies and urban design solutions that are easy to implement and that can offer multiple benefits, from an environmental, social, and economic standpoint. Finally, we created a catalogue of local materials and native species thought of for the bioclimatic context of Corrientes and that, according to the same principles, can be designed for other regions.

The first catalogue, as we can see in Graphs 37-40, is dedicated to sustainable drainage techniques and integrates technical information with a design for local implementation in the city of Corrientes. The catalogues are divided into systems for infiltration, conduction, transportation, and gathering. They include information on the main advantages and the feasibility of its adaptation to diverse objectives and contexts.

In order to achieve the integration of the sustainable urban drainage techniques and solutions based on nature and informal settings, we collected the most relevant techniques for the context, and we connected them with sections of green infrastructure that are potentially implementable in low-income neighborhoods.
CUTLAGE OF SUSTAINABLE DRAINAGE TECHNIQUES
Sustainable Drgage Systems (SuDS)

ADVANTAGES
1. Runoff reduction and peak flows | less drainage network maintenance
2. Pollutant reduction | cost reduction of sewage treatment
3. Locally produced materials | costs reduction
4. Locally extracted materials | costs reduction
5. Native vegetation | increased growth and low maintenance
6. Temperature reduction | saving in energy use
7. Extended durability | maintenance reduction
8. Few materials | cost reduction and easy implementation
9. Existing natural condition | implementation cost reduction
10. Scarce resources | implementation cost reduction
11. Flood risk reduction
12. Natural absorption of CO2
13. Increase of albedo compared to surface of waterproof asphalt
14. Heat island effect reduction

FEASIBILITY
1. Slope recommended at less than 10%
2. Slope greater than 5% requires restrictions (partitions / heat sinks)
3. Large surface space
4. Soil with infiltration capacity
5. Soil conducive to the presence of water
6. 1m (min.) distance to aquifer
7. Not vulnerable Aquifer
8. Clean waters in accordance with regulations
9. Waters without suspended sediments
10. Consider velocities that avoid sedimentation
11. Light traffic
12. Permanently available water

SUDS TECHNIQUES
1. CONTROL SYSTEMS IN ORIGIN

2. FILTRATION AND TRANSPORTATION SYSTEMS

3. STORAGE AND TREATMENT SYSTEMS

Permeable pavements
Cellular pavements
Infiltration ditches
Rain gardens
Channels and streams
Green gutters
Filtering gutters
Retention ponds
Wetlands

GRAPH 37
ECOLOGICAL DESIGN
GRAPH 38
CATALOGUE OF SUDS ROADS TECHNIQUES

CELLULAR PAVEMENTS

- Layer of soil
- Permeable pavers
- Sand bed
- Top granular filter
- Porous material
- Permeable geotextile

CANALES Y ARROYOS

- Layer of soil
- Gravel
- Rocks
- Ap Horizon
- E Horizon
- Blt 1
- Blt 2

CELLULAR PAVEMENTS

- Layer of soil
- Permeable pavers
- Sand bed
- Top granular filter
- Porous material
- Permeable geotextile

CHANNELS AND STREAMS

- Layer of soil
- Gravel
- Rocks
- Ap Horizon
- E Horizon
- Blt 1
- Blt 2

GREEN DUCTS

- Ap Horizon
- E Horizon
- Blt 1
- Blt 2
- Vegetable soil with sand 20%
- Drainage (sand and gravel)

RAIN GARDENS

- Capture volume
- Ap Horizon
- E Horizon
- Blt 1
- Blt 2
- Vegetable soil with sand 20%
- Drainage (sand and gravel)
GRAPH 40
CATALOGUE OF PUBLIC SPACE TECHNIQUES

GREEN DUCTS

FILTER DUCTS

POROUS PAVEMENTS

WETLANDS

ECOLOGICAL DESIGN

ECOLOGICAL DESIGN

PERM roll folder

Sand bed

Super granular filter (base)

Porous material (sub-base)

Permeable geotextile sheet

FILTER DUCTS

WETLANDS

ECOLOGICAL DESIGN

ECOLOGICAL DESIGN

PERM roll folder

Sand bed

Super granular filter (base)

Porous material (sub-base)

Permeable geotextile sheet
The second catalogue resumes a series of typologies of nature-based solutions for public spaces that could be implemented in informal neighborhoods, which in this case we based in Corrientes.

In **Graph 41**, for example, it shows that streets with green ditches canalize rainwater runoff in a continuous system that filters and drains in the Arroyo Pirayui. The green ditches are open, shallow, and densely vegetated. This is an adaptation technique for climate change, which in rainy seasons stores and slows the flow of water, preventing flooding. The actors involved in this typology are mainly from the government, as the principal function of these roads is water drainage infrastructure. These can also serve as ecological corridors and walkway networks.

**Graph 42** shows the type C-2 typologies of tree-lined boulevards. They work as main streets in the neighborhood, which continue the connections with the neighborhoods adjacent to the city. The streets can incorporate continuous lines of trees and different kinds of urban equipment in their sidewalks. The permeable pavements and the linear tree grates are techniques for adaptation to climate change that allow for water absorption, and the trees improve the environmental quality of these walkways, reducing the contamination emitted by vehicles and the effect of heat islands. They also have repercussions on economic activities along the boulevard. They can be developed through government initiatives, within urban plans, by institutions and public or private equipment, or even in collaboration with community organizations.

**Graph 43** presents typologies of rain gardens. These, as well as slowing and infiltrating superficial water flows, provide a space in a neighborhood that can be appropriate for families to plant vegetation, preferably native species, such as productive urban gardens. These are techniques for adaptation to climate change that reduce contamination and improve air quality and energy behavior in streets. It also benefits social cohesion. Its character as a secondary route allows for its use for alternative transport, such as cycling or walking. The actors can be individuals but also neighborhood organizations and neighborhood groups.
The streets with green gutters channel the rainwater runoff in a continuous system that filters and drains into the Arroyo Pirayui. The green gutters are open, shallow channels that are thickly vegetated. This is a technique of adaptation to climate change that during the rainy session, stores and slows down water movement to avoid flooding. The actors that develop this typology are mainly governmental, since the function of these streets is mainly to do with drainage infrastructure. These roads can serve as ecological corridor connectors and walking pathways.

MENDOZA DROUGHTS

The Mendoza canal system constitutes an urban water model successful. In addition to draining rainwater, Mendoza ditches are used to irrigate the urban woodland.

ACTORS
National government, Regional government, Local government.

PROGRAM
Ecological corridor, walkways.

BENEFITS
- Reduction in risk of flooding (reduction of water runoff)
- Reduction of urban pollutants
- Natural absorption of CO2
- Easy implementation
- Low implementation cost and maintenance (local materials and native vegetation)
- Comfort/shade of urban wooded area

LOCAL MATERIALS
C-2 function as main streets within the neighborhood that form connections with adjacent neighborhoods as well as the city. The streets can incorporate continuous lines of trees and various urban equipment in its sidewalks. Permeable pavements and linear tree pits are techniques for adapting to climate change conditions that allow for the absorption of water and trees, improving the environmental quality of these pathways, reducing pollution that is emitted by vehicles, and the heat island effect. They also have repercussions on the economic activities of the boulevard. They can be developed from government initiatives, within urban plans, by public, or by private institutions and facilities, or even with the collaboration of community organizations.

The renovation of the Paseo de St. Joan, a project by architect Lola Domenech, proposes an urban green corridor that prioritizes pedestrian use, reducing traffic in streets that lead to various living and vegetative areas.

**ACTORS**
National government, Public institutions, Multilateral agencies and international banks, Academia, Private Companies, Civil society.

**PROGRAM**
Ecological corridor, Public transport, Market, Walkway

**BENEFITS**
- Reduction in risk of flooding (reduction of water runoff)
- Reduction of urban pollutants
- Natural absorption of CO2
- Easy implementation
- Low implementation cost and maintenance (local materials and native vegetation)
- Generation of public space
- Comfort/shade of urban wooded area

**LOCAL MATERIALS**
The rain gardens, in addition to delaying and infiltrating the surface flow of water, provide a space that may be appropriated by neighborhood families to plant the vegetation (which would preferably be native) in a similar way to urban gardens. It is a technique for adaptation to climate change that reduces pollution and improves air quality and performance energy in the streets. It also benefits social cohesion. Its character as a secondary vial allows it to be used by alternative forms of transport, such as cycling or walking. The actors can be individuals but also neighborhood organizations or groupings of neighbors.

VEGETABLE PLOT, CYCLE-LANE, WALKWAY

ONG, LOCAL COMMUNITY, PRIVATE INDIVIDUALS

- Reduction in risk of flooding (reduction of water runoff)
- Capture of urban pollutants
- Capture and improvement in water quality before its infiltration
- Natural absorption of CO2
- Easy implementation
- Low implementation cost and maintenance (local materials and native vegetation)
- Comfort/shade of urban wooded area

LOCAL MATERIALS
Graph 44 presents typologies of permeable streets. In the remainder of the internal streets of the neighborhood, the diminished transit is taken advantage of to propose a permeable pavement, both in pedestrian and vehicular routes, encouraging the use of local materials such as crushed brick. As well as the advantages of permeable pavements for the protection against flooding and the albedo effect, permeable pavements present the opportunity to involve the community in its construction and maintenance, fostering local identity and belonging.

Permeable pavements present the opportunity to involve the community in its construction and maintenance, fostering local identity and belonging.
In the rest of the internal streets of the neighborhood, the decrease in traffic is used to propose a permeable pavement in both the pedestrian and vehicular areas, promoting the use of local materials such as crushed brick. In addition to the advantages that permeable pavements offer for protection against flooding and the albedo effect, these roads present the opportunity to involve the community in its construction and maintenance to foster feelings of belonging.

**GRAPH 44**
**TYPOLOGIES. TYPE C+ PERMEABLE STREETS**

**LOCAL MATERIALS**

*Library Park Julio Santo Domingo, Bogota*

The park generates diverse permeable zones through the use of a large variety of materials, from native vegetation to permeable cobblestones, crushed brick and even recycled materials.

**ACTORS**
ONG, civil society, local community

**PROGRAM**
Cycle-lane, Walkway

**BENEFITS**
- Reduction in risk of flooding (reduction of water runoff)
- Passive irrigation of nearby vegetation
- Natural absorption of CO2
- Easy implementation
- Low implementation cost and maintenance (local materials and native vegetation)
- Opportunity to involve the community in the construction and maintenance.
Graph 45 focuses on linear parks and green squares. Depressions in the topography of the park allow for the slowing down of superficial flow towards a lagoon, mainly due to gravity, through a system of terraced wetlands that contain and filter water. With this, there is a decreasing of floods, generating a great richness in biodiversity and green spaces of leisure for the communities. The initiative can be governmental, due to the continuity with other green systems at a larger scale, and due to its importance in drainage infrastructure. Community groups can also be involved in its development. They can be part of the ecological corridors at a larger scale, or humid urban forests that function as techniques of both mitigation of and adaptation to climate change. They also become spaces of learning and communing with nature.

A particular type of green square would be floodable squares (Graph 46). As well as generating a recreational and leisure space for the neighborhood, these squares contain rainwater, diminish the risk of flooding and work as a technique for adaptation to climate change. The court at the center of the park is a landmark or meeting space for the neighborhood and has major health, social, and cultural benefits for the community, improving lifestyle. This typology can be undertaken by government initiatives and/or by the community.

Graph 47 shows the combination of wetlands and lookout points. The border between the boulevard and the lagoon allows for a wide public space for different uses, from walkways to cycle paths, to lookout points, potentially created from local wood that is extended over the water. The lagoon, which works as a technique of mitigation of climate change, is a space for the accumulation of existing natural water that is given new value through this intervention by virtue of its landscape and attractiveness for the neighborhood. The actors involved can be governmental due to the ecological value of this urban landscape. Numerous recreational activities can be undertaken in this space, such as the sharing of knowledge about the local ecology of Corrientes. Along with the linear park, the wetland can be used as an infrastructure for the cleaning of water to recuperate the area.

The third catalogue collects and systemizes local materials of production and extraction for the implementation of the green infrastructure techniques, with existing knowledge and abilities, and commitment from the local community. In the case of the city of Corrientes, there is local gravel extraction as well as the production of bricks and wood for construction. There is also the possibility of recycling waste material: plastic (an existing initiative in Corrientes) or tires that exist in informal settlements. For other locations, a specific investigation into the materials available in the region and in each informal settlement would have to be carried out. Graphs 48 and 49 show a series of materials and prefabrications produced locally in the Corrientes area.

The fourth catalogue collects vegetal species. These, as with the materials, should be specific to each locality. In this case, it is important to look at the information of the Risk Atlas with respect to the landscape in which each informal settlement is inserted. The use of native species is vital in the development of green infrastructures, as it is these that develop more resilience to climate change and are a more sustainable use of hydraulic resources or of ground types. In this way, the local scale can contribute to the health of ecosystems at a larger scale, forming biodiversity connections through the urban fabric. Reconnecting landscapes that were fragmented due to deforestation or the loss of bodies of water, the landscapes increase their resilience and ecosystem services, and in this way can protect cities from the challenges and effects of climate change. These also include fruit and aromatic herb species for areas of horticulture, where fruits and spices can be produced for the community. Graphs 50 and 51 show the main native vegetal species of Corrientes, adapted for design and implementation solutions based on nature. Each species is detailed in terms of type of growth, height, land type, and climate.
The depressions in the topography of the park slow down the surface runoff towards the main lagoon by its gravity, through a system of terraced wetlands that contain and filter the water, reducing flooding and generating great wealth of biodiversity and green recreational spaces for the community. The initiative may be governmental due to its continuity with other green systems on a larger scale and due to its importance in the drainage infrastructure. Community groups can also get involved in development. It can be part of larger-scale ecological corridors or humid urban forests, which function as techniques of both mitigation and adaptation to climate change. It is also a space for learning and meeting with nature.


LOCAL MATERIALS

VILLA SOLDATI
BUENOS AIRES

The park uses techniques of phytoremediation. The contamination of the Riachuelo and Arroyo Cildañez, near the floods, make it a very vulnerable area. The restoration uses flora that is native to wetlands, which have reduced 45% organic pollutants.

ACTORS

National government, regional government, local government, civil society

PROGRAM

Wetland, urban forest, ecological corridor, park, cycle-lane, walkway.

BENEFITS

- Reduction in risk of flooding (reduction of water runoff)
- Reduction of urban pollutants
- Capture and improvement in water quality before its infiltration
- Natural absorption of CO₂
- Regulation of the area’s temperature
- Reduction of noise pollution
- Easy implementation
- Generation of public space
In addition to generating a recreational and leisure space for the neighborhood, these sunken squares contain rainwater, reducing the risk of flooding, and functioning as a technique of adaptation to climate change. The court in the center of the neighborhood is the landmark or meeting space and brings enormous benefits to the health, education and social and cultural activities of the community, improving their quality of life. This typology can be carried out at the initiative of the government and/or the community.

**GRAPH 46**

**TYPOLOGIES. E2-FLOODABLE PLACES**

**GRAPH 46**

**TYPOLOGIES. E2-FLOODABLE PLACES**

**INUNDABLE ZANJÓN PARK**
**SANTIAGO DE CHILE**

Allows the overflow of the natural watery ditch in times of strong rain, keeps flooding under control in the parks and drives the rainwater to different levels. In the dry seasons, the space is converted into a park.

**ACTORS**
Public institutions, multilateral agencies and international banks, private companies, academia, civil society, local community.

**PROGRAM**
Square, courts, playing field, park, market

**BENEFITS**
- Reduction in risk of flooding (reduction of water runoff)
- Reduction of urban pollutants
- Capture and improvement in water quality before its infiltration
- Natural absorption of CO2
- Regulation of the area’s temperature
- Reduction of noise pollution
- Generation of public space that is adaptable to climatic conditions

**LOCAL MATERIALS**

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ECOLOGICAL DESIGN

IDB
The meeting point between the boulevard and the lagoon allows a wide public space for various uses, from walks and cycle-lanes to viewpoints, potentially made of local wood, that extend out over the water. The lagoon, which works as a mitigation technique to climate change, is a space that accumulates natural existing water, which is revalued through this intervention for its scenic value and attractiveness for the neighborhood. The actors involved can be governments for its ecological value in the urban landscape. Numerous recreational activities can occur in this place, such as the disclosure of knowledge about the local ecology of Corrientes. Together with the linear park, it can be used as a cleaning infrastructure for the area’s recuperation.

DE LA FAMILIA PARK
SANTIAGO DE CHILE

The park recuperates the rivera of the Río Mapocho and rehabilitates a degraded industrial zone. It also functions as a meander of the river that generates, on the one hand, calm waters that can be used for nautical activities, and on the other, a continuous walkway along the river.

ACTORS
National government, regional government, local government

PROGRAM
Wetland, park, cycle-lane, viewpoint, walkway

BENEFITS
- Reduction in risk of flooding (reduction of water runoff)
- Reduction of urban pollutants
- Capture and improvement in water quality before its infiltration
- Natural absorption of CO2
- Regulation of the area’s temperature
- Reduction of noise pollution
- Revitalisation of the existing lagoon
- Generation of public space

LOCAL MATERIALS

The park recuperates the rivera of the Río Mapocho and rehabilitates a degraded industrial zone. It also functions as a meander of the river that generates, on the one hand, calm waters that can be used for nautical activities, and on the other, a continuous walkway along the river.

ACTORS
National government, regional government, local government

PROGRAM
Wetland, park, cycle-lane, viewpoint, walkway

BENEFITS
- Reduction in risk of flooding (reduction of water runoff)
- Reduction of urban pollutants
- Capture and improvement in water quality before its infiltration
- Natural absorption of CO2
- Regulation of the area’s temperature
- Reduction of noise pollution
- Revitalisation of the existing lagoon
- Generation of public space

LOCAL MATERIALS
GRAPH 48
CATALOGUE OF LOCAL MATERIALS

ADVANTAGES OF THE MATERIAL
- Locally produced materials | reduction of costs
- Locally extracted materials | reduction of costs
- Permeable material

USES: SUDS TECHNOLOGIES
- Porous pavements
- Cellular pavements
- Rain gardens
- Infiltration ditches
- Filtration ditches

OTHER USES
- Pedestrianised bridges
- Urban equipment

NATURAL MATERIALS | LOCAL EXTRACTION
- Fine gravel
- Medium gravel
- Coarse gravel

RECYCLED MATERIALS | LOCAL PRODUCTION
- Debris gabions
- Bricks made of recycled plastic
- Tires

FABRICATED MATERIALS | LOCAL PRODUCTION
- Brick
- Wood

CRUSHED MATERIALS | LOCAL PRODUCTION
- Brick
- Wood
**Wood**

Local production of wood

01 Extraction and chopping up of raw materials
02 Classification of logs according to diameter
03 Removal of bark and stones or sand that are embedded in it
04 First side cuts of the trunk: extraction of surplus
05 Definitive width and length of each part: removal of impurities and flattening of laterals
06 Classification, markation and fixation of the pieces according to dimensions and quality

**Brick**

Local production of brick | Brickwork community of Corrientes

01 Extraction of raw materials
02 Mixture and stepping on raw material
03 Molding of bricks
04 Brick drying
05 Baking of bricks

**Gravel | Extracted from the Parana River**

Fine gravel
Medium gravel
Coarse gravel

**Crushing | Local Products**

Crushed brick
Crushed wood
Debris
BITTER ORANGE
Citrus sinensis
- Tree: evergreen
- Height: 3-6m
- Soil: no restrictions
- Climate: sensitive to cold

SWEET ORANGE
Citrus sinensis
- Tree: evergreen
- Height: 7-10m
- Soil: fertile, well drained, cool / sandy loam
- Climate: humid climate

GRAPEFRUIT
Citrus x paradisiacus
- Tree: evergreen
- Height: 5-10m
- Soil: deep, well drained, cool / sandy loam
- Climate: warm

PINEAPPLE BUSH
Ananas comosus
- Perennial Height: 1-2m
- Soil: drained
- Climate: tropical, sensitive to cold

BLUEBERRY BUSH
Vaccinium myrtillus
- Perennial Height: 0.5-2.5m
- Soil: acidic, loose and with good porosity
- Climate: varies according to type

PITANGA TREE
Eugenia uniflora
- Tree: evergreen
- Height: up to 7.5m
- Soil: no restrictions (except saline)
- Climate: tropical and subtropical, sensitive to cold

AGUAY TREE
Pouteria gardneani
- Tree: deciduous
- Height: up to 12m
- Soil: deep, rich and well drained
- Climate: humid, subtropical, tolerant to frost

JABOTICABA TREE
Pouteria gardneani
- Tree: deciduous
- Height: up to 20m
- Soil: rich, deep and well drained
- Climate: humid

AVOCADO TREE
Persea americana
- Leaves: deciduous
- Height: up to 20m
- Soil: rich, deep and well drained
- Climate: humid

MANDARIN ORANGE TREE
Citrus reticulata
- Tree: evergreen
- Height: 3-5m
- Soil: deep, wall drained, fracs to sandy loams
- Climate: subtropical

FIG TREE
Ficus carica
- Tree: deciduous
- Height: 4-10m
- Soil: deep, dry in nature
- Climate: subtropical

LEMON TREE
Citrus x limon
- Tree: evergreen
- Height: 3-6m
- Soil: deep, wall drained, fracs to sandy loams
- Climate: warm
DESIGNING A FUTURE FOR CLIMATE CHANGE
It is crucial that the most vulnerable groups with the least access to resources, such as the inhabitants of informal settlements, are not excluded from this transformation process. In Latin America, like in other parts of the world, informal settlements are most vulnerable to the effects of climate change, in spite of being those that least contribute to the emission of greenhouse gases.

If on the one hand it is urgent to improve the living conditions in these neighborhoods, the security of their inhabitants, and their work opportunities and economic development, it is also important to develop solutions that put the environment and efficient use of resources at the center of attention, creating a leap forward that would avoid repeating the destructive impacts of the traditional industrial model.

As Cynthia Smiths shows in her exhibition, *Design with the Other 90%*, it is important to activate the capabilities of all citizens and think of design solutions that promote inclusion by addressing multiple social groups, long-term investment in multimodal public transport, and regional focuses on collaboration.¹

The projects chosen by Smith suggested that we can all learn a lot from emerging and developing economies about how to create innovative solutions with limited resources and challenging environmental conditions.² The Vertical Gymnasium by Matías Pinto D’Lacoste, Mateo Pinto, and Urban Think Tank³ for example, or the Community Cooker by Planning System⁴ a simple stove designed to convert waste into secure, clean, and cheap energy in Kibera – the largest informal neighborhood in Nairobi – could serve remote neighborhoods elsewhere.⁵

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² Smith, C. E. (October 2011).
⁵ Smith, C.E. (2011). Planning System Services in 2010 created the Community Cooker Foundation to expand the project beyond the informal city of Kibera.
The green infrastructure projects presented in this document – such as the requalification of Calle 107, or the Barrio Moravia, the Parque Tiuna Fuerte, the interventions developed for the communities in Palomera, or the new green and slow infrastructures proposed by the Ruta Naturbana and Mapocho 42K – are examples of interventions that are capable of generating positive effects for the climate and environment. Among them, the improvement of air and soil quality, controlling the microclimate of neighborhoods, managing water, and absorbing carbon, while creating quality public spaces of social and metropolitan integration.

This document introduces a series of products of knowledge that are being developed in the Inter-American Development Bank in the framework of “Ecological Design” in order to support communities and professionals in improving urban quality and resilience toward climate change in the informal city. The series, “Ecological Design: Strategies for the Vulnerable City” will propose guidelines for diagnoses and design solutions in order to reduce the vulnerability of informal settlements and their inhabitants, through a series of documents that include an atlas of risk, case studies of nature-based solutions for public space, a catalogue of sustainable housing, and a manual for applied ecological design.
INTRODUCTION

2. Rio de Janeiro, Brazil. Photography: Connor Fuller
3. Valparaiso, Chile. Photography: Jonny Joka
4. Colombia. Photography: Karl Groendal
5. Ecuador. Photography: Michael Shink

ECOLOGICAL JUXTAPOSITIONS, CHAPTERS 1-4

Inés Benítez Gómez

“Ecological juxtapositions” is a project by Inés Benítez Gómez developed for this publication. It is specifically aligned with the struggle against urban inequality and climate change, projected towards sustainable cities and communities in Latin America. Through these images, the horizon of understanding, sensibility, and discourse about these subject aim to communicate on another level of abstraction.

PUBLIC SPACE PROJECTS, CHAPTER 3:

Paseo Urbano de la Calle 107, Proyecto Urbano Integral (Colombia, Medellín, 2004-2005)
Credits: Urbam EAFIT. Alejandro Echeverri.
Photography: Diana Moreno.

Plaza Estacional (Caracas, Venezuela, 2015)
Credits: Gabriel Vi conti Stopello (AGA studio).
Photography: José Bastidas.

Parque Cultural Tiuna el Fuerte (Caracas, Venezuela, 2015)
Credits: Lab.Pro.Fab.
Photography: Iwan Baan

Rocinha Mais Verde (Rio de Janeiro, Brazil, 2011-2014)
Credits: Green my Favela – Lea Reakow and Hortas Cariocas (Júlio César Barros).

Huerta en Manguinhos (Rio de Janeiro, Brazil, 2012-2020)
Credits: Green my Favela – Lea Reakow and Hortas Cariocas (Júlio César Barros).

Parque Fazendinha (São Paulo, Brazil, 2017-2020)
Credits: Movimiento Fazendinhando.

Parque Trazando Sonrisas (Sucre, Venezuela, 2017-2019)
Credits: Trazando Espacios.

Parque Bibliotecaa España (Medellín, Colombia, 2005-2007)
Credits: El Equipo Mazzanti – Giancarlo Mazzanti & ARCHITECTS.

Parque de la Familia (Santiago, Chile, 2010-2015)
Credits: Cristián Boza Wilson – Boza Arquitectos.
Photography: Felipe Díaz Contardo

Parque en el Arroyo Xicoténcatl (Tijuana, Mexico, 2019)
Credits: Teller Capital.
Photography: Gabanna
Represo Colosio (Nogales, Mexico, 2019)
Credits: Teller Capital.
Photography: Rafael Gamo

La Palommera (Caracas, Venezuela, 2016-2017)
Credits: Enlace Arquitectura – Eliza Silva.

Recuperración del Morro de Moravia (Medellín, Colombia, 2009-2014)
Credits: Cátedra UNESCO de Sostenibilidad, Universidad Politécnica de Catalunya (UPC) – Dr. Jordi Morató i Farreras.
Photography: Environment Secretary – Medellín Council.

Parque Ecológico Lago de Texcoco (Mexico City, Mexico, 2019-2028)
Credits: Iñaki Echeverría.

Corredor Socio-Ecológico de los Cerros Orientales (Bogotá, Colombia, 2007-2020)
Credits: Diana Wiesner.

Rutas Naturbanas (San Jose, Costa Rica, 2015-2020)
Credits: Fundación Rutas Naturbanas – Federico Cartín.

Mapocho 42K (Santiago, Chile, 2010-2020)
Credits: M42K_Lab UC – Sandra Iturriaga.
Photography: M42K Lab. F. Croxatto

Bio Medellín 2030 (Medellín, Colombia, 2011-2020)
Credits: Área Metropolitana del Valle de Aburrá – URBAM, BIO 2030.

Sistema Integrado de Información y Gestión para la Refuncionalización y Recuperación del Arbolado Urbano (Mendoza, Argentina, 2017-2018)
Credits: UNICIPIO (Council for the Coordination of Public Policies for the Metropolitan Area of Mendoza).