
Natural territory, urban growth and climate change in the Parana River Delta and Rio de la Plata estuarine system¹.

Author:

Verónica M.E. Zagare

Architect, MSc in Urban Economics,

PhD candidate,

Faculty of Architecture, Delft

University of Technology.

Email: v.m.e.zagare @tudelft.nl

This overview aims to show the ecological significance of the Parana Delta and the Rio de la Plata system, the main drivers of change and the possible consequences of urban growth and climate events. It also addresses the vulnerabilities and potentials of the system and the interrelationships that take place on it. The recognition of the present situation and future natural and human-caused effects remains of vital importance for the development of planning adaptation strategies. The methodology of this document is clearly descriptive, trying to give an impression of the reality of the region and to introduce this case study to the international debate. Previous investigations on the area often considered Parana Delta's islands and the coasts of Parana Delta and Rio de la Plata estuary as separate units in terms of their landscape, ecology or geography. Nevertheless, they are geomorphologically related and they suffer the effects of the same natural and urban processes, so they can be considered parts of a larger system. Besides natural evolutionary changes, urban growth has also expanded throughout the entire region establishing a complex net of economic relationships. During the latest decades, the urban development of Buenos Aires Metropolitan Area, the larger conurbation of the Argentina, has expanded North-West towards the Parana Delta. Simultaneously, the front of the Delta has advanced due to natural processes of sediment accumulation, displacing towards South-East. Both processes are taking place at the same time, converging in a context where the lack of resources, infrastructures and urban planning is an obstacle for the implementation of sustainable actions and adaptation strategies to face climate changes. In the need of theories and planning strategies, this paper aims to introduce the present scenario in order to understand the dynamics coexisting within the system and to present some possible planning strategies for the area from a regional and local perspective.

Draft version, January 2011

Keywords: Urbanized Deltas, Urbanism, Sustainability, Drivers of change, Parana Delta.

¹ This article is "under review" because is about to be published shortly.

INTRODUCTION

A complex coexistence of natural environment, urban patterns and climate changes takes place in estuarine delta systems (Meyer et al., 2009). The resulted landscape differs from one region to another depending on ecological, political, economical and technological frameworks.

The *Cuenca del Plata* is the second major hydrographical basin of South America. It covers 3.1 million km² distributed in five countries (Argentina, Brazil, Bolivia, Uruguay and Paraguay) and drains to the Atlantic Ocean through the Parana Delta and Rio de la Plata estuarine system. (see Figure 1). This complex system constitutes a dynamic sedimentary geologic-hydrologic unit located between the coasts of Argentina and Uruguay,

and has a vital relevance not only for the region -a high populated area with more than 22 million inhabitants- but also for the hydrology of South American continent.

According to the Intergovernmental Panel on Climate Change (Magrin et al., 2007), the Rio de la Plata, the Amazon and the Orinoco carry into the Atlantic Ocean more than 30% of the renewable freshwater of the world.

In spite of having a great biodiversity and natural resources, Latin America is threatened by stress on water quality, unequal distribution of the resource, lack of infrastructures and strong climate changes. The studied case is representative of the Latin American situation, where the impact of non planned urban growing processes together with political, economical, institutional and technological limitations lead into an unsustainable use of the land.

Four issues will be presented on this paper: the natural processes that take place on the estuarine system, the dynamics of economic development and urban expansion, climatic trends and the possible future effects that the interaction of the three previous factors may have on the region. Finally, a set of planning adaptation strategies will be suggested from a regional and local perspective in order to search for a sustainable balance between natural systems and urban growing processes within the uncertainty of climatic variations.

OVERVIEW OF THE SYSTEM

The Parana Delta and Rio de la Plata are related from a geomorphological point of view. They formed during the Pliocene, Pleistocene and Holocene Epochs, due to transgressive-regressive events related to glacier and inter-glacier periods characterized by rapid increases and decreases of sea level (Cavalotto and Violante, 2005). Although each river has its own geographic characteristics, they are linked by water currents, they share sediments and are exposed to the same climatic forces. For studying purposes, the Parana Delta and the Rio de la Plata estuary are going to be analyzed as a unique system (PD-RP system) in order to address both regional and local specific issues related to natural and human drivers of change.

The Parana River is the third largest river in the American Continent after the Mississippi in the United States and the Amazonas in Brazil. Located in South America, it runs through Brazil, Paraguay and Argentina, where it flows into the Rio de la Plata. Its length is 2570 km and its basin surface is 1.5 million km². The two initial tributaries are located in Brazil – Paranaiba River and Grande River-, but the most important tributary is the Paraguay River, located in the homonymous country. Compared to other rivers, the Parana is half the length of the Mississippi but it has similar flow –Parana River's flow is 17000 m³/s and Mississippi's 16000 m³/s-, and is twice as long as the Rhine, but it has eight times its flow. The Parana River is the unique river in the world that flows into another river (Consejo Federal de Inversiones, 1962) and it is the most important river of La Plata basin (Paraná sub-basin covers 48% of the total surface of the basin). In the river mouth, the Parana joins the Uruguay River forming the 250 km-long Rio de la Plata, a wide estuary which presents a maximum width of 230 km.

The funnel-shaped transition between the Parana River and the Rio de la Plata is the Parana Delta (PD), one of the largest coastal wetlands systems of Argentina, which covers a surface of 14000 km². The subaerial Delta presents a variable width, from 18 km to 100 km, and according to landscape parameters it can be divided into three zones: Superior, Medium and Lower Delta, where can also be found other landscape sub-units. The PD is a young area with a balance between erosion and sedimentation processes, influenced by freshwater tides and South Eastern winds. This complex territory is located near the most populated region of Argentina and faces spatial pressures of three important metropolitan regions:

Buenos Aires Metropolitan Area (BAMA) –the largest conurbation of the country, with a population of around 12 million inhabitants-, Gran Rosario Metropolitan Area –the third urbanized area of the nation, with more than 1.2 million inhabitants-, La Plata city -0.7 million inhabitants- and Santa Fe –with almost 0.5 million inhabitants- (see Figure 2).

Two water sources influence the delta: local precipitations and large rivers –Parana, Guleguay, Uruguay and Rio de la Plata- (Malvárez, 1997). The surface of the delta is increasing due to sediment accumulation –Parana River transports 160 million tons of sediments per year- which also produces a continuous advance of the delta front. One of the two subfronts of the River, called Parana de Las Palmas sub-front, presents an important advance –from 50 to 100 m/year- parallel to the coast of Buenos Aires city. A study of the INA (Instituto Nacional del Agua) revealed that in the last 200 years the delta's surface increased in 200 km² and that the delta front will reach the coast of Buenos Aires city in 110 years (Pittau et al., 2004). This phenomenon would produce a big transformation of the coastline (see Figure 3).

NATURAL ENVIRONMENT

Argentina has an immense territory but hydric resources are unbalanced: La Plata basin covers 30% of the national territory and is estimated to have 85% of the total available superficial water of the country (World Bank, 2000). The ecological functions of the system are highly relevant not only for the national and regional economic development but also for the environmental stability. For addressing the ecological relevance of the PD-RP system it is necessary to understand the dynamics that take place on it, related to the conditions of being a delta, a wetland and an estuary.

The system as a delta: according to Wright (1985), deltas are coastal accumulations shaped by interacting fluvial and marine forces. Their morphological characteristics and their development are a consequence of a conflict relation between coastal and fluvial processes. The main question is about the regime of the river that transports sediments, the coastal processes that take place in the river mouth and climate factors (Morgan, 1970). The formation of deltas is related to the capacity of the rivers to deposit sediments faster than they can be removed by the

receptor's quiet waters regimes (Kandus and Malvárez, 2002).

The system as a wetland: wetlands are permanently flooded systems or soils that are saturated with water during long periods (Mitch and Grosselink, 1993). The water usually comes from different sources such as sea, rivers, rains or groundwater, and the hydrological regime is diverse (Kandus and Malvárez, 2002).

The system as an estuary: an estuary is coastal water partially confined that presents a free connection with open sea, being the sea water diluted by fresh water. Parker and Marcolini (1992) consider that it is possible to restrict the term estuary to the study of the dynamics between both types of water. Estuary's dynamics are related to the effects of the tide according to the magnitude of the swell and the river. The PD is an important key for flood control: 0.4 hectares of wetland can store 6000 m³ of floodwater without needing engineer structures (Davis, 1993). It is also vital for groundwater replenishment, because under La Plata basin there are important underground reserves of fresh water for agricultural, industrial and domestic uses, such as the Puelches, Pampeano, Parana, or the Guarani aquifer which spreads over 1.2 million km² through Brazil, Uruguay, Paraguay and Argentina storing approximately 45000 km³ of water. According to Ramsar Convention on Wetlands (Davis, 1993), although freshwater ecosystems cover 1% of the earth's surface, they are home for 40% of the world's species and are responsible of 52% of the total amount of services provided by all the ecosystems of the world (Constanza et al., 1997). The biodiversity held in wetlands helps retaining nutrients and sediments, purifying water by removing nitrogen, phosphorous and other chemicals and retaining carbon dioxide. They also contribute with shoreline stabilization protecting the land from storms surges, winds, waves and other climatic events. The PD is protects lands from the strong South-Eastern winds during the so called "Sudestadas", which usually have severe consequences causing floods due to the increase of the Rio de la Plata water level. At the present, PD is focus for national and international conservation actions: there are several protected areas, a National Park and a Biosphere Reserve of 886 km² located in San Fernando, declared under UNESCO's Man and Biosphere program.

ECONOMIC AND URBAN DYNAMICS

The PD and Rio de la Plata's coasts are located on the most populated area of Argentina and in the middle of Sao Paulo- Santiago de Chile commercial corridor of the Mercosur (economic agreement between Brazil, Paraguay, Uruguay and Argentina). Although Chile, Bolivia and Venezuela are not included in the original constitution of the Mercosur, they participate in the commerce through this terrestrial corridor and through the fluvial Parana-Paraguay waterway.

According to the SAGPyA (Secretaría de Agricultura, Pesca y Alimentos de la República Argentina), most productive units located on the delta's islands are small. In fact, 92% of the units have less than 200 ha, 6% have from 200 to 1000 ha and the rest 2% are large production units of more than 1000 ha. The delta is suitable for forestry, especially for the plantation of softwoods such as willow and poplar, and for stockbreeding, which has increased five times from 2003 to 2008. On the contrary, fishing has decreased due to the intensive practice for commercial purposes and changes in the species habitat caused by infrastructure works (constructions of dikes, ports and bridges). Intensive agriculture is practiced too, being important the cultivation of soya, maize and wheat. Thus, tourism and leisure activities are relevant for the Delta. Visitors can navigate down the river, practice water sports, fish and rest in luxury lodges, representing an important income for the community. Along the PD there are several industrial poles strategically located, close to ports. The most important are located in the Departments of San Nicolas, Ramallo, Zarate and Campana. Most of the commercialized products are wood, woodwork, metalwork, aluminium frames, electrical goods, motor parts, paper, corn and other grains, oil, alcohol, iron, concrete and fuel.

URBAN EXPANSION

The urban sprawl of Buenos Aires Metropolitan Area has grown since the middle of the twentieth century changing considerably from 1990s, when the urbanization process extended reaching the Lower Parana Delta. In the BAMA lives the 31% of the national population and participates in 53% of the GDP (Gross Domestic Product) covering less of 0.15% of the country's surface (Atlas Ambiental de Buenos Aires, 2010). Even though agricultural activities are relevant, the importance of the region is

also linked to industrial activities and services encouraged by the proximity to Buenos Aires city and to the ports of Parana River and Rio de la Plata. The economic evolution was possible due to the national industrialization process that took place since the middle of the twentieth century, but the recurrent changes in the economic situation and in politic frameworks led to a disperse and unarticulated territorial conformation (Atlas Ambiental de Buenos Aires, 2010). The process of technological innovation, transport facilities and economic uncertainty encouraged the formation of agglomeration economies, so companies share diverse resources within the region and face the economic instability with lower adaptation costs (Atlas Ambiental de Buenos Aires, 2010). In spite of the national economic recession, the BAMA has maintained its primacy over any other conurbation of the country and has expanded its boundaries together with the demographic growth and the appearance of new centralities. The new centres appeared along corridors of "wealth and modernity" (Pírez, 2001), mostly oriented to North and West. The advance of the urban expansion along the Northern corridor reached the Lower Parana Delta, which is now part of the metropolitan area.

The urbanization process on delta's islands differed from the continental area. Historically, before the colonization, the delta was inhabited by aboriginal communities. After the Spanish arrival, the islands were occupied by foreign travellers who cultivated fruits and practiced forest logging (Galafassi, 1996; Sierra, 1967). The unplanned settlements were precarious, disperse and the access to the lands was difficult due to the lack of infrastructure. The goods that they produced were sold in Buenos Aires city and they were not used for exportation purposes. The possession and distribution of the lands was not regulated by the Estate and at first, they were considered a non productive natural beauty. In 1856, a decree granted lands to the Municipalities of Tigre (originally called "Las Conchas"), San Fernando and others to exploit and cultivate them. In 1888 was sanctioned the Law N° 2072 -Ley de Islas-, the first focused on the measurement and distribution of PD lands. The law established ways for transferring plots to the occupants by selling them. Thanks to it, 55% of the lands were transferred to private domain (Galafassi, 1996). After that, without having a planning strategy, in 1934 the Law N° 4207 allowed the sell of coastal lands with access to navigable

waterways to private investors who shaped the delta and privatized the access to some areas of the coast.

On the other hand, the metropolitan space of Buenos Aires grew from the centre of the city to the periphery along the railways. Since 1940s, due to the industrialization process, new centralities appeared offering commercial spaces, banks, and health and education services, relatively close to the city centre – from 5 to 20 Km- (Ciccolella, 2002). During the 1990s, economic liberalization led to the expansion of new centralities further away from the city centre, establishing a complex network and creating new spatial relations along highways. The urban sprawl grew considerably in what Ciccolella (2002) calls a “Transition of the Urbanization Process” (TPU), a process that generates new territorial formations as a result of the alteration of the spatial and temporal conditions of production, circulation and consumes. The political and economic context of 1990’s promoted the development of private urbanizations for medium and high classes, most of them located in the North area of the province, even reaching the Parana Delta coastline (see Figure 4). The scenario was characterized by a deep Reform of the Estate, new urban laws, a decrease of the inflation rate, an increase of External Direct Inversions due to the decrease of the international rates of interest, the construction of transport infrastructure and the absence of a coordination role of the Estate (Ciccolella, 2002). This situation encouraged private brokers to appropriate lands near the River, especially of the Lower part of the Delta. The islands of the medium and upper area were forgotten, a lot of people moved to urban areas and the population that remained on the islands ended up immersed in poverty. Besides, due to the exodus of the medium and high classes who emigrated to live in private urbanizations, Buenos Aires city stabilized its population and BAMA tripled it. The number of private urbanizations or gated communities increased from 100 to 350 in the period 1995-2000 and today it is more than 400. According to Ciccolella (2002) and Cohen (2007), the surface occupied by private urbanizations is 500 km² (larger than Buenos Aires city). In spite of the growth of the highest classes, in the period 2001-2006, 60% of the new inhabitants settled on informal precarious settlements –called villas and asentamientos-, forced by the economic crisis (Cravino et al., 2009). The result was a polarised scenario full of social inequities: luxurious

gated communities and informal settlements located on lands sensitive to flooding.

URBAN PATTERNS

The BAMA and the PD are defined by different urban patterns according to land uses and socio- economic parameters: a traditional urban space characterized by the regularity of the Spanish first settlements -city of Buenos Aires and urban centres of provincial departments-; private urbanizations or gated communities -new artificial landscapes-; slums or informal settlements; agricultural lands; industrial poles; disperse housing –on the islands- (Figure 5). These urban patterns have different impacts on the territory and are also affected by climate change and shaped by socio-economic dynamics. All the patterns coexist on a polarised space without following any regional urban law which rules the relations between them. The only national rule is the Law N° 8912 of 1977 which establishes minimum parameters for settlements, division of habitable plots, uses and infrastructures and gives to each department the responsibility of local urban planning. This law introduced the concept of “country club”, or so called gated community, which plans has to be approved by the local municipality.

When local authorities are responsible for their own urban development and planning policies, they can act accurately according to people’s needs because they are aware of local problems. On the other hand, jurisdictional boundaries prevent the recognition of regional dynamics so the cooperation between local authorities is needed, because usually, environmental and socio-economic processes do not coincide with political divisions. When local governments act alone, they are not strong enough to deal with real estate developers and social pressures, being difficult to find a balance between each group’s needs. In this area, the process of recognizing the metropolitan expansion as a regional issue which needs regional authorities and policies is not yet in the short-term political agenda (Pírez, 2001). On the contrary, each municipality has to manage local pressures, small budgets and social needs. In a context of lack of resources and organization, regional matters and adaptation to climate are not considered urgent issues so they are not priority.

CLIMATIC TRENDS

According to the Intergovernmental Panel on Climate Change (IPCC), Latin America is the most urbanised region in the developing world with 75% of urban population (Magrin et al., 2007). Although it covers 20 million km² full of natural resources and biodiversity, it is very sensitive to climate variations and urban dynamics. This vulnerability is related to weak political, economical and infrastructural frameworks together with income inequality, high poverty levels and population growth. In the PD-RP system, unplanned urban growth and socio-economic polarisation intensify the vulnerability of people living on coastal lands, naturally sensitive to climate variations. In the last decades, regional climatic trends had shown strong changes in short periods of time, coinciding with global change. The new climate conditions of the region are a consequence of the increase of temperatures in the Antarctica, the ENSO (El Niño Southern Oscillation) events and the displacement of the anticyclone of the South Atlantic Ocean, caused by the increase of Greenhouse Gases emissions -GHG- (Barros and Bejarán, 2005). The conjunction of climate change and urban growing processes generates big transformations which must be taken into account to design sustainable strategies to guarantee the permanence of natural resources permitting economic development.

Studies elaborated by the IPCC (Magrin et al., 2007) show that temperature in Latin America will increase from 0.4°C to 1.8°C by 2020 and from 1.0°C to 7.5°C by 2080. Temperature rising can cause acceleration in glacier retreat affecting water availability and hydropower generation in some parts of South America. It can also influence evaporation rates, which are necessary to be balanced with the precipitation level to pre-empt floods and guarantee aquifers refill. In South-Eastern South America – SESA-, precipitations are usually caused by mesoscale convective systems –MCS- (Barros et al., 2006) which are very destructive as they cause heavy rainfalls in large territories during short periods of time. This is a distinctive issue considering that SESA has shown the largest trend in precipitation of the world during last century (Giorgi, 2002). The increase in rainfalls is related to higher river discharges: for every one percent change in precipitation there is a two percent change in streamflow (Berbery et al., 2006). In La Plata Basin, precipitations increased 16% comparing the periods of 1951–1970 and 1980–1999, and streamflows increased 36% (Barros and Bejarán, 2005). The isohyets suffered a change too, displacing

towards west more than 200 km in some parts of the Argentina, increasing the cultivable surface in around 100000 km². The variability in precipitations caused by climate change phenomenon must be considered for the planning of new settlements and the administration of water resources. Nevertheless, the uncertainty in climate projections of precipitations prevents the development of confidence scenarios (Berbery et al., 2006).

EXTREME HYDROLOGICAL EVENTS (EHE): INFLUENCE OF ENSO (EL NIÑO SOUTHERN OSCILLATION), “SUDESTADAS” AND FLOODS.

The ENSO is a cycle that takes place in the tropical Eastern Pacific Ocean and is characterized by a change of temperature and pressure of surface waters. The warming phase is called El Niño and the cooling phase is called La Niña. ENSO is the main source of variability in South America and in spite of not always being followed by precipitations, it has a great influence on them (Berbery et al., 2006). In the PD-RP system, precipitation variability is mostly influenced by ENSO during the warming phase El Niño and during neutral periods –phases between El Niño and La Niña (Berbery et al., 2006).

In 1983 a dramatic flood caused the Parana Delta to lose its buffer condition leaving almost 40000 km² under the water (World Bank, 2000). The flood was associated with El Niño and repeated in 1998 (Berbery et al., 2006) with a similar result: 45000 km² of flooded lands (Barros and Bejarán, 2005). Some years later, in 2003, a part of Santa Fe city –a city located on the Parana’s coastline- got under the water because of the sudden growth of the Parana’s tributary, the Salado River, also caused by precipitations. These three events occurred in a short time-frame among other floods that are taking place since 1970. The trends set for this area show that the amount of rainfall and the number of extreme events is increasing so the scenario is not stable but changing rapidly.

The perception of risk is composed by a social environmental dimension –vulnerability- and a hydrological dimension –natural threat- (Chamorro, 2006). Although floods are not as striking as hurricanes or earthquakes, they cause lethal consequences in human settlements and in terms of biodiversity. According to the World Bank (2000), Argentina is among the 14 countries most affected by floods, and has estimated losses of around 1.1% of its

GDP. For instance, the 2003 Santa Fe's flood showed a high social vulnerability, with a result of an unfinished polder under the water, hundreds of evacuated people and a millionaire loss.

Strong South-Eastern winds also cause extreme floods due to the increase of water level. This phenomenon is called *Sudestada* and affects low areas of Buenos Aires and PD, blocking the natural drainage of the waters, streams and channels (Coronel and Menendez, 2006). Apart from the *Sudestadas*, The PD suffers from periodic floods due to extraordinary discharges of the Parana River (Re and Menendez, 2006).

IMPACTS OF CHANGES

Natural evolutionary changes, urban growing processes and climate variations are immersed in a cause-effect cycle, influencing each other. This process, together with the vulnerabilities of the local context, has short and long term consequences on the natural resources and also on the built environment and society. Water resource is highly affected been altered in its quality and quantity. Furthermore, other impacts are being generated by human activities resulting from economic development. These effects must be taken into consideration when designing adaptation strategies and planning policies, in order to regulate the activities to lower the negative impacts and reach a more sustainable development.

VULNERABILITY OF THE WATER RESOURCE

Water is highly sensitive to climate change, intensive agricultural practice –dependent of agrochemicals-, deforestation, urban development, construction of dams and fluvial navigation. The resource is already under pressure and it constitutes a relevant factor for the biologic diversity of the La Plata Basin (Chamorro, 2006). Any change produced in the area alters the resource's quality and quantity, having irreversible effects. Even though the PD-RP system constitutes one of the most important sources of superficial water of the nation (World Bank, 2000), it also has the major concentration of urban and economic activities, which have the highest pollution potential. The 30% of the total demand of water is satisfied by underground aquifers, which have a great extension and capacity, being exploited by all the socioeconomic levels for all uses. The aquifers that contribute to the underwater demand of the region are the Pampeano, Puelches and Parana. The most wanted

aquifer for domestic use is the Puelches because of its quality, but over-exploitation has produced the salinisation and pollution of the water, so the resource is being substituted by the Rio de la Plata. On the other hand, after having closed 500 wells that extracted underground water, another effect was generated: the lack of use of the aquifer produced an increase of underground water level in some parts of the province, causing basement and tunnel floods, and wells and septic tanks overflowing.

EFFECTS OF ECONOMIC ACTIVITIES

i) Agriculture and Stockbreeding.

Agriculture and agro industry are very important as they represent 62% of Argentina's GDP (De Simone, 2006) and thus are highly dependent on climate change. As it was described before, the increase of precipitations and the displacement of isohyets cause changes in agricultural boundaries and types of crops. Since the agricultural activity has an annual cycle, it becomes easier for farmers to adjust to climate changes with the help of biotechnology development. Nevertheless, when extreme events occur, the loss is dramatic mostly for small farmers who have to manage the problem without anticipation. Stockbreeding is one of the most affected activities, so when there is a flood, cattle have to be moved to other lands to be saved even from death. Stockbreeding and agriculture also impacts on the environment and needs to be practiced with limits to prevent pollution of water and soil. Even though cattle faeces can be used as fertilizer, the excess has negative implications turning the water cloudy and producing the extinction of some species. Pesticides and agrochemicals used in intensive agriculture pollute soil and water producing alterations in the cycle of nutrients and adding substances that can be dangerous or even lethal for humans –in case of domestic water consumption- and other species.

Apart from stockbreeding, the cultivation of some crops such as soya gained importance during the past three decades, motivated by the increase of international prices, the simplicity of the process and the profitability of the crop. Since 1970s, the cultivation of soya has grown considerably, reaching 41% of the total national exportations (De Simone, 2004). This crop can be planted on degraded surfaces without needing much fertilizing and, as some types of transgenic soya are very strong, farmers kill useless weeds by using glyphosate –a very contaminant

herbicide-. Although soya is possible to be combined with other crops such as wheat or corn, which makes the crop very cost-effective and ecologic, it is not always cultivated in that way. In fact, it is planted alone, as a unique crop, producing soil degradation and underground water pollution.

ii) Biomass burning.

Delta's wetland is an area of rich pasture subject of periodic fires caused by natural forces (droughts and high temperatures) and by farmers who want to make the land suitable for forestry by cleaning it of certain dry grass and rodents. The first consequence of fires is the removal of vegetal biomass and the subsequent change of surface albedo –coefficient of reflection of solar radiation-: the ground acts like a black surface absorbing more solar radiation during the day and losing more energy during the night. Although biomass burning presents some advantages such as the stimulation of the development of new vegetation species, nutrient recycling and liberation of seeds for new germination (Kandus 2009), it has also a lot of disadvantages which vary depending on the moment of the year and the intensity of the fire. Among all the damages, fires produce loss of animal biodiversity and of certain seeds, soil degradation –or even total loss-, exposition of roots and rhizomes, changes in vegetation structure, soil erosion due to changes in water and temperature increase, carbon liberation and GHG emission. This practice is harmful not only for the ecosystem but also for the people, and it is not regulated by any kind of legislation (Kandus, 2009). Fires are difficult to be controlled and they can expand rapidly burning large territories; they produce noxious fumes that cause breathing deceases; they generate smoke and ashes that covers cities and roads -producing traffic accidents- and fall into the water and soil. In 2008, the fires were difficult to control due to a period of drought and lack of rains, causing the burn out of 12% of the wetland and spreading ashes up to 250 km away (Figure 6).

iii) Deforestation

The change from forest to crop or pasture can influence not only evaporation rates, vegetation types, roughness or air circulation, but also precipitations and temperature (Da Silva Dias 2006). Studies developed in the Amazonas show that deforestation can cause a decrease in precipitation of around 20%, and an increase in temperature of around 2-3°C. Latin America produces 4.3% of global GHG emissions and

deforestation and land use changes are responsible of 48.3% of this percentage (Bates 2008). Deforestation is expected to be one of the most serious environmental disasters of the region, related to intensive agriculture and urbanization processes. If the increase in agricultural lands due to economic advantages of some crops is not controlled, it will produce a great impact on environment. Urbanization process also produces changes that impact on global and local climate. The concentration of population, buildings and urban infrastructures can generate Urban Heat Island effect (UHI), increasing local temperature up to 5°C (Wilby 2007). Although Buenos Aires city -and specially BAMA- is constantly growing, studies show that UHI effect is not representative up to this moment (Barrucand et al., 2009); as the city is expected to grow, new studies will have to be developed. Urbanization leads to a decrease in wind speed, evapotranspiration and absorbing surfaces. It also generates more energy and introduces new sources of heat such as transports, air conditioners, industrial machines, artificial heating, etc. (Wilby 2007). These characteristics cooperate to GHG emissions increase and to EHE and water related risks vulnerability.

iv) Land use changes

The case of private urbanizations that are being developed in the BAMA, and especially on PD is important to be studied. The number of private gated communities quadrupled in less than ten years (Ciccolella 2002) offering new services and functions. In a context of lack of regional planning and land use legislation, this type of developments needs to be regulated. The pressure of real estate developers is so strong that they manage to shape the space according to satisfy their own benefits. The result is a privatized coast and a landscape full of mixed spots of wealth and poverty. The impact that these private inversions generate on the territory is worrying: they change the topography by creating new artificial landscapes conformed by lagoons, bridges and marinas, they introduce new animal and vegetal species, alter natural ecosystem and generate waste. They also need infrastructure –because they mostly settle on floodplains without services- so they depend from great inversions that include real estate developers, services companies and government. In spite of generating negative externalities, these developments also produce positive effects on labour market creating new jobs and improving economy. Outside

any value judgement, they are an expression of the social and economic changes and they need to interact together with the other types of housing patterns, as a part of the urban fabric.

Another type of urban pattern is the informal settlement. They are located on residual spaces between private urbanizations, next to the urban core of the departments, on the coasts or even on the islands. The major problem of these settlements is the lack of infrastructures and sanitary conditions, and the high vulnerability to climatic events. The absence of water and a formal sewer system encourage people to extract water from wells and to make informal septic tanks. This is a source for water and soil pollution and can be very harmful for health, favouring the spreading of diseases.

Industrial poles also impact on territory generating heat, GHG emissions and waste. It is necessary to regulate the location of the industries to balance the environmental damage and monitoring the pollutants caused by them.

v) Coasts and hydrological erosion.

Erosion implies the washing away of soil by the action of water, which carries sediments and contaminants. Although most part of the coastal erosion existing on PD is caused by natural processes –water currents- it is also induced by stockbreeding, intensive agriculture and navigation. Ships can increase the erosion by generating strong currents as they pass parallel to the coasts. The consequences of extreme erosion are the change of sedimentation rates, the loss of the capacity to regulate the hydrologic regime and flooding. According to a study made in the INTA (Instituto Nacional de Tecnología Agraria) based on the use of Wischmeier and Smith's Universal Soil Loss Equation -USLE- (Roose, 1996), the Delta has a low-medium risk with an expected loss of 30 to 60 ton/ha per year (Orué et al. 2007).

vi) Energy Production.

Lower Parana River and Rio de la Plata are influenced by the activities that are developed on the upper sections of the river, in Brazil and Paraguay. Along the Parana River there are four hydroelectric power stations (Ilha Solteira and Jupiá – Brazil-, Itaipú – Brazil and Paraguay-, and Yaciretá –Paraguay and Argentina-). Hydropower is the most important and renewable source of energy representing 19% of the world's electricity production. It is expected that global climate change, hydrological erosion and

sedimentation will cause water stress, affecting hydropower generation and affecting the whole PD-RP system.

vii) Fluvial navigation.

Some years ago, the technologic advance made road transportation more profitable than fluvial transport. Nowadays the situation is reversing due to the energetic crisis and increase on fuel costs. Parana River is a relevant fluvial route that can be navigated by ships of different draughts, even overseas shipping. It is connected with the Atlantic Ocean through artificial channels made under the Rio de la Plata and with the Paraguay River thanks to the Parana-Paraguay Waterway project (currently under development). In the future, this waterway could be able to interact with Orinoco River –Venezuela- and Amazon River –Brazil-. The major impact that navigation produces on the area is coastal erosion, and dredging and infrastructure construction causes alterations in the habitat of fish and other species.

PLANNING STRATEGIES FOR ADAPTATION

The complexity of the PD-RP system is related to the diversity of the drivers of change and also to the different scales of the problems. A multiplicity of jurisdictional authorities and competences coexist on the area, which is already divided into 18 local governments (Municipalities or Departments) under 3 sub national jurisdictions (3 Provinces), and the National Government. This diversity of functional authorities with huge territorial reach is a context of complex institutional arrangements and conflicting visions on the area's role. The result is a fragmentary, inadequate and unsuccessful design and implementation of policies and measures, including water management and land use strategies.

In this context, it is necessary to design and apply measures for adapting to climate change and demographic dynamics in order to reach sustainability and governance. The major challenge for developing and implementing adaptation strategies is dealing with the diversity of impact scales, actions and actors and the uncertainty of climate drivers and trends. The network of relations is so large that is not possible to plan unique unilateral top-down actions. Strategies for adaptation must be designed and applied at different scales by the diversity of actors, according to their responsibility and involvement in the problem.

From a regional urban planning perspective, it is necessary to first understand the territory according to the natural, urban and economic dynamics beyond the administrative divisions. Economic development and urban growth have overwhelmed jurisdictional borders, so they must be included in a regional agenda. The questions here are: Does this agenda exist? How can regional programs be implemented? Is any institution capable of acting in a regional scale? Is it possible to create regional policies and programs without interfering with local existing ones?

Regional planning needs for a structural vision, as an outline to define how the policies or programs are going to be achieved, which authorities will implement them and through which instruments. A regional strategic plan could be organized depending on the specific conditions of the area and the interrelations that take place in the system. According to the overview presented in this document, it is possible to detect four axes of actions to develop strategies: Environmental quality, Safety, Life quality and Coordination of actions. Some key measures to be developed within each axis involve:

Environmental quality: conservation of the wetland and its ecological functions and development of analysis of the territory using GIS technology at different scales to detect the problems and the most vulnerable areas; control of the activities developed on the delta and the coasts through soil management and control of the use of pesticides in intensive agriculture; improvement of crop cultivation – planning of planting dates and types of crops-; safe water provision, groundwater protection and water recycling; aquifer management –control of extraction rhythm, amount of wells and geographical distribution-; modification of industrial processes; reduction of energy demand –sustainable buildings- and optimization of water consumption.

Safety: construction of infrastructures and management of flooding risks through the development of defences in the necessary cases; maintenance of the artificial canals and water sewages.

Life quality: inclusion of the informal sectors into the formal market through the urbanization of the settlements and the regulation of each private development to guarantee benefits and prevent negative impacts; construction of infrastructures to

include all the sectors of the population in water, sewage, electricity and gas systems; development of a land uses plan according to the present situation.

Coordination of actors: coordination between governmental and nongovernmental institutions; cooperation of the involved actors (from organizations to individuals) is relevant to achieve governance. The role played by the local institutions is crucial to detect specific problematic and future potentials and to implement local programs to follow the regional guidelines.

The advantages of a regional plan are innumerable in terms of overcoming politic-administrative fragmentation of the space to avoid polarisation of resources. Nevertheless, the main problem here is that a political intention to do that is needed and that this kind of plans have long term results and must resist government changes. Thus, the large extension of the territory makes difficult to benefit all the inhabitants, which are living in unequal conditions and have different types of needs. In this complex scenario, the role of local governments is crucial because they are closer to the people, they are aware of their needs and they have been elected by them, legitimizing the process of decision-making. When working locally, the amount of drivers of change reduces so does the number of actors intervening in the conflicts. Besides, local governments are able to interact with local communities to build a balanced relation between top-down and bottom-up actions and policies.

From this perspective, it is not possible to think regional without thinking local. Regional plans must give a framework of actions and must guarantee the stability of the policies, coordinating the relations between stakeholders and reducing negative externalities. On the other hand, local authorities must understand their role within the system and provide concise tools to apply regional intentions considering local needs, through the involvement of citizens into the processes of policy-making.

Some experiences that could have positive results are being developed in Argentina, such as the creation of regional authorities able to manage environmental problems overcoming jurisdictional obstacles -the COFEMA (Consejo Federal de Medio Ambiente)- . Furthermore, from a local scope, examples of community programs are being developed by Universities and non profit organizations with the objective of creating environmental awareness and improving governance.

CONCLUSION

This overview introduces the drivers of change that coexist in the Parana Delta and Rio de la Plata estuary, in order to understand the complexity of the territory and outline some strategic measures considering the changing nature of the system. This kind of knowledge of the relations within a system is needed to interpret the specificity of the situation and design accurate strategies avoiding a 'one fits all' policy approach.

It is possible to conclude that this case is a good example of a complex delta system where the natural evolution of a rich environment collides with the unplanned urbanization and exploitation of the lands. In a little over than 500 years of history, the lands witnessed radical social and political changes and suffered the effects of a strong demographic growth and the consequent exploitation of the natural resources. The vast extension of the territory, the great number of coexisting jurisdictions and the multiplicity of stakeholders contribute to turn the development and implementation of regional policies a difficult task. As a consequence, the increase of housing demand produced by population growth, immigration and social and economical changes shaped a polarised expansion of the metropolitan area towards the new sedimentary lands of the delta. This expansion is being developed without an integral land use plan and leads to an unsustainable occupation of the territory. Thus, in times of climate changes, extreme hydrologic events threaten the area striking a great part of the population living in highly vulnerable areas. All these matters should be taken into account when designing strategic measures addressing adaptation to changes. When there is lack of resources in a context of social instability, it seems difficult to make governments include adaptation into the agenda. Then, the role of planners and designers is to participate actively in the process of decision making together with the community through the different instances of participation that every democratic government offers. Local governments are the most important communication channel between people and provincial or national authorities and constitute a crucial start point for the designing of bottom-up policies.

Nowadays, the international urban debate focuses not only on the built environment but also on the intrinsic capacity of cities to adapt to changing conditions,

adding climate change as a variable to be considered in every cities' planning (Aerts and Dircke, 2010). Although it was shown in this document that the Argentinean case is relevant in terms of changing environment, hydrology and resources availability, it is not globally well known yet. The final objective of this review is to present this Latin American case to contribute to share and exchange experiences and knowledge between delta cities.

References

1. Aerts, J., Dircke, P., 2010. Climate change in delta cities, in: Dircke, P., Aerts, J. and Molenaar, A., Connecting Delta Cities, City of Rotterdam, pp.14-19.
2. Atlas Ambiental de Buenos Aires, 2010. <http://www.atlasdebuenosaires.gov.ar>, (Decree N°627, Government of the City of Buenos Aires).
3. Barros, V., Clarke, R., Silva Dias, P.S., 2006. Climate Change in La Plata Basin. Trends in the Hydrological cycle of the Plata basin, IAI-CONICET, Buenos Aires.
4. Barros, V., Bejarán, R., 2005. Adaptación al cambio climático en Argentina. Dónde estamos?, CIMA-CONICET, Buenos Aires.
5. Barrucand, M., Camillioni, I., Rusticucci, M., 2009. Characterization of the Urban Heat Island at Buenos Aires city. Facultad de Ciencias Exactas y Naturales UBA, Buenos Aires.
6. Bates, B.C., Kundzewicz Z., Wu, S. and Palutikof, J.P. (Eds.), 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.
7. Berbery, E., Doyle, M., Barros, V., 2006. Regional Precipitation Trends, in: Barros, V., Clarke, R., Silva Dias, P.S., Climate Change in La Plata Basin. Trends in the Hydrological cycle of the Plata basin, IAI-CONICET, Buenos Aires, pp. 61-73.
8. Cavalotto, J., Violante, R., 2005. Geología y geomorfología del Rio de la Plata, in: Barrio R., Etcheverry, R., Cavalle, M.F., Llambias, E. (Eds.), Geología y Recursos Minerales de la Provincia de Buenos Aires, La Plata. pp. 237-254.
9. Chamorro, L., 2006. The main services and problems of water resources. , in: Barros, V., Clarke, R., Silva Dias, P.S., Climate Change in La Plata Basin. Trends in the Hydrological cycle of the Plata basin, IAI-CONICET, Buenos Aires, pp. 104-116.
10. Ciccolella, P., 2002. La metrópolis postsocial: Buenos Aires, ciudad – rehén de la economía global, in: Actas

- del Seminario Internacional "El desafío de las áreas metropolitanas en un mundo globalizado. Una mirada a Europa y América Latina", Barcelona.
11. Cohen, M., 2007. Convertibilidad, crisis y desafíos para el futuro: 1991-2006. In Gutman, M. and Hardoy, E. (Eds.), Buenos Aires 1536-2006. Historia Urbana del Área Metropolitana. Ediciones Infinito, Buenos Aires, pp. 270-313.
 12. Consejo Federal de Inversiones, 1962. Recursos Hídricos superficiales. Serie: Evaluación de los Recursos Naturales de la Argentina. Tomo IV, Volumen 1. Buenos Aires.
 13. Constanza R., Darge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital, *Nature*, Vol 387, pp. 253-260.
 14. Coronel, G., Menendez, A., 2006. Physiography and Hydrology, in: Barros, V., Clarke, R., Silva Dias, P.S., *Climate Change in La Plata Basin. Trends in the Hydrological cycle of the Plata basin*, IAI-CONICET, Buenos Aires, pp. 44-60.
 15. Cravino, M., Del Río, J., Duarte, J., 2009. Magnitud y crecimiento de las villas y asentamientos en el Área Metropolitana de Buenos Aires en los últimos 25 años. http://www.fadu.uba.ar/mail/difusion_extension/090206_pon.pdf
 16. Da Silva Dias, 2006. Background on other regional aspects: land use change, aerosols and trace gases, in: Barros, V., Clarke, R., Silva Dias, P.S., *Climate Change in La Plata Basin. Trends in the Hydrological cycle of the Plata basin*, IAI-CONICET, Buenos Aires, pp. 127-134.
 17. Davis, T.J., (Ed.), 1993. *Towards the Wise Use of Wetlands. Convention on Wetlands of International Importance especially as Waterfowl Habitat*. Ramsar Convention Bureau, Gland.
 18. De Simone, C., 2004. *Análisis de las Exportaciones Agroindustriales. Período 2003-2004*, Secretaría de Agricultura Ganadería Pesca y Alimentos, Buenos Aires.
 19. De Simone, C., 2006. *El desempeño del sector agropecuario y agroindustrial en el nuevo milenio*, Secretaría de Agricultura Ganadería Pesca y Alimentos, Buenos Aires.
 20. Galafassi, G., 1996. *Aproximación al Proceso Histórico de Asentamiento, Colonización y Producción en el Delta del Paraná (Argentina)*. Estudios Sociales N°11, Ediciones UNL, Santa Fé, pp. 139-160.
 21. Giorgi, F., 2002. Variability and trends of sub-continental scale surface climate in the twentieth century, *Climate Dynamics* No.18, pp. 675-691.
 22. INDEC (Instituto Nacional de Estadísticas y Censos, Argentina), www.indec.mecon.ar.
 23. Kandus, P., Malvárez, A., 2002. Las islas del Bajo Delta del Paraná, in: Borthagaray, J. (Ed.), *El Río de la Plata como territorio*. Ediciones Infinito, Buenos Aires.
 24. Kandus, P., 2009. Incendios de 2008 en el Delta del Río Paraná, Argentina. Informe técnico, INTA, UNSAM, LETyE, UBA, Buenos Aires.
 25. Magrin, G., Gay García, C., Cruz Choque, D., Gimenez, J.C., Moreno, A.R., Nagy, G.J., Nobre, C., Villamizar, A., 2007. Latin America. *Climate Change 2007: Impacts, Adaptation and Vulnerability*, in: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, pp.581-615.
 26. Malvárez, A., 1997. *El Delta del Río Paraná como mosaico de humedales*, Laboratorio de Ecología Regional, Departamento de Ciencias Biológicas. Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Buenos Aires.
 27. Meyer, H., Morris, D., Waggonner, D. (Eds.), 2009. *Dutch Dialogues -New Orleans/Netherlands*, SUN, Amsterdam.
 28. Mitch, Grosselink, 1993. *Wetlands*, Van Nostrand, New York.
 29. Morgan, 1970. *Deltaic sedimentation: Modern and Ancient*, Society of Economic Paleontologist and Mineralogist Special Publication, 15.
 30. Orué, M., Larreta, P., Cabria, F., 2007. Expansión de la frontera agrícola en Argentina y erosión hídrica: mapas de riesgo utilizando el Modelo Usle con apoyo de SIG, in: *Teledetección - Hacia un mejor entendimiento de la dinámica global y regional*: <http://www.aet.org.es/congresos/xii/arg24.pdf>
 31. Parker, G., Marcolini, S., 1992. Geomorfología del Delta del Paraná y su extensión hacia el Río de la Plata, *Revista de la Asociación Geográfica Argentina* No.47, Buenos Aires, pp. 243-249.
 32. Pérez, P., 2001. Cuestión Metropolitana y gobernabilidad urbana en la Argentina, in: Vázquez Barquero, A., Madoery, O., (Eds.), *Transformaciones globales, Instituciones y políticas de desarrollo local*, Edit. Homo Sapiens, TOP Virtual Lybrary.
 33. Pittau, M., Sarubbi, A., Menéndez, A., 2004. *Análisis del avance del frente y el incremento areal del Delta del Río Paraná*, Instituto Nacional del Agua (INA), Buenos Aires. http://laboratorios.fi.uba.ar/lmm/congresos/cc_delta_frentes_conagua_may05.pdf
 34. Re, M., Menendez, A., 2006. Impacto del cambio climático en las costas del Río de la Plata. *Revista Internacional de Desastres Naturales, Accidentes e Infraestructura Civil*. Vol. 7(1), pp. 25-34.

35. Roose, E., 1996. Land husbandry - Components and strategy, Orston, Montpellier.
36. Sierra, V., 1967. Historia de la Argentina. Consolidación de la labor pobladora (1600-1700). Editorial Científica Argentina, Buenos Aires.
37. SAGPyA (Secretaría de Agricultura, Pesca y Alimentos de la República Argentina), www.sagpya.mecon.gov.ar
38. Torres, H., 2001. Cambios socio territoriales en Buenos Aires durante la década de 1990, Eure, Vol.27 (80), Santiago de Chile.
39. Wilby, R., 2007. A review on climate change. Impacts on the built environment. Built Environment Vol.33 No.1, pp. 31-45.
40. Wright, 1985. River Deltas, in: Davis, R. (Ed.) Coastal Sedimentary Environments, Springer-Verlag, New York.
41. World Bank, 2000. Argentina: Gestión de Recursos Hídricos. Elementos de Política para su Desarrollo Sustentable en el Siglo XXI. Informe No.20729-AR. Vol. 1. Oficina Regional de América y el Caribe.

Figure 2: Urban dynamics of the system: Metropolitan areas and departments

Figure 3: Historic advance of the Delta front. Source: author's elaboration from the basis of Pittau et al. (2004).

Figure 4: Location of gated communities. Expansion 1991-2001. Source: author's elaboration from the basis of Torres (2001).

Figure 5: Urban patterns in the area (housing).

Figure 6: Fires produced by drought and biomass burning practice (2008). Burnt out of 12% of the delta. Image source: NASA.

List of Figures

Figure 1: Location of PD-RP system.

Figures

Figure 1: Location of PD-RP system.

Location of Parana Delta ad Rio de la Plata estuarine system.



Figure 2: Urban dynamics of the system: Metropolitan areas and departments

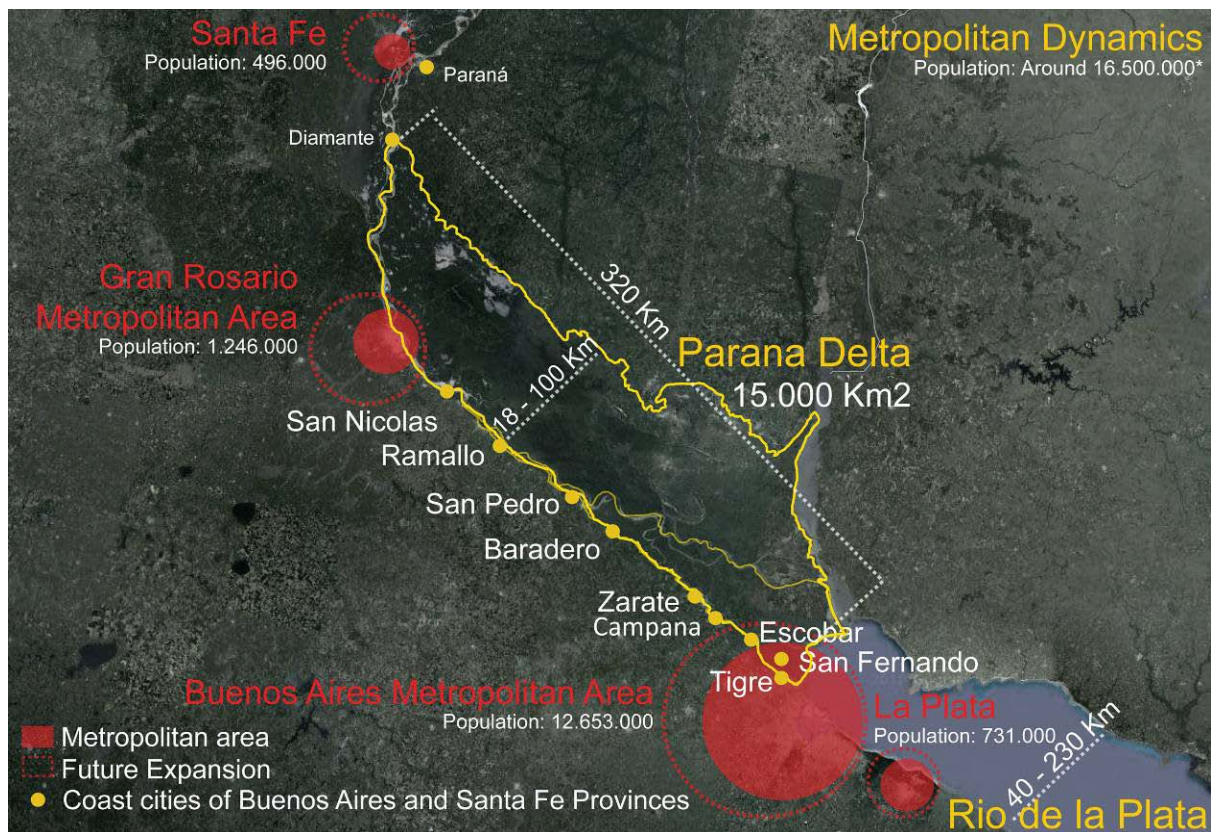


Figure 3: Historic advance of the Delta front. Source: author's elaboration from the basis of Pittau et al. (2004).



Figure 4: Location of gated communities. Expansion 1991-2001. Source: author's elaboration from the basis of Torres (2001).

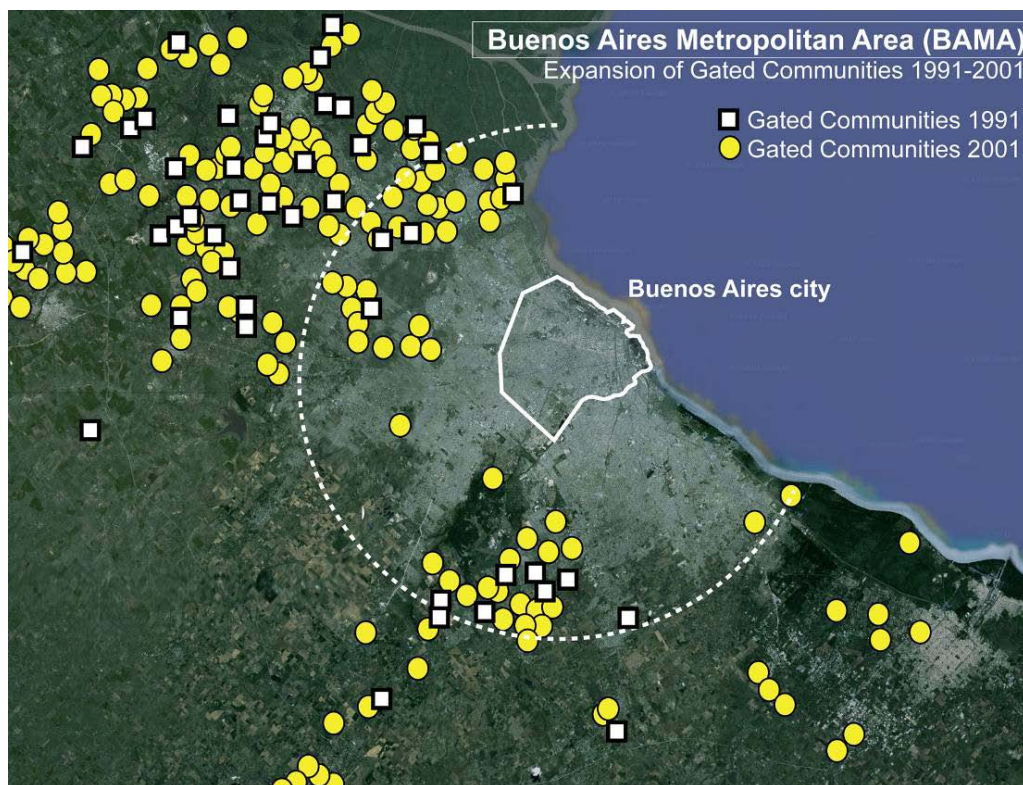


Figure 5: Urban patterns in the area (housing).

Urban patterns (housing)

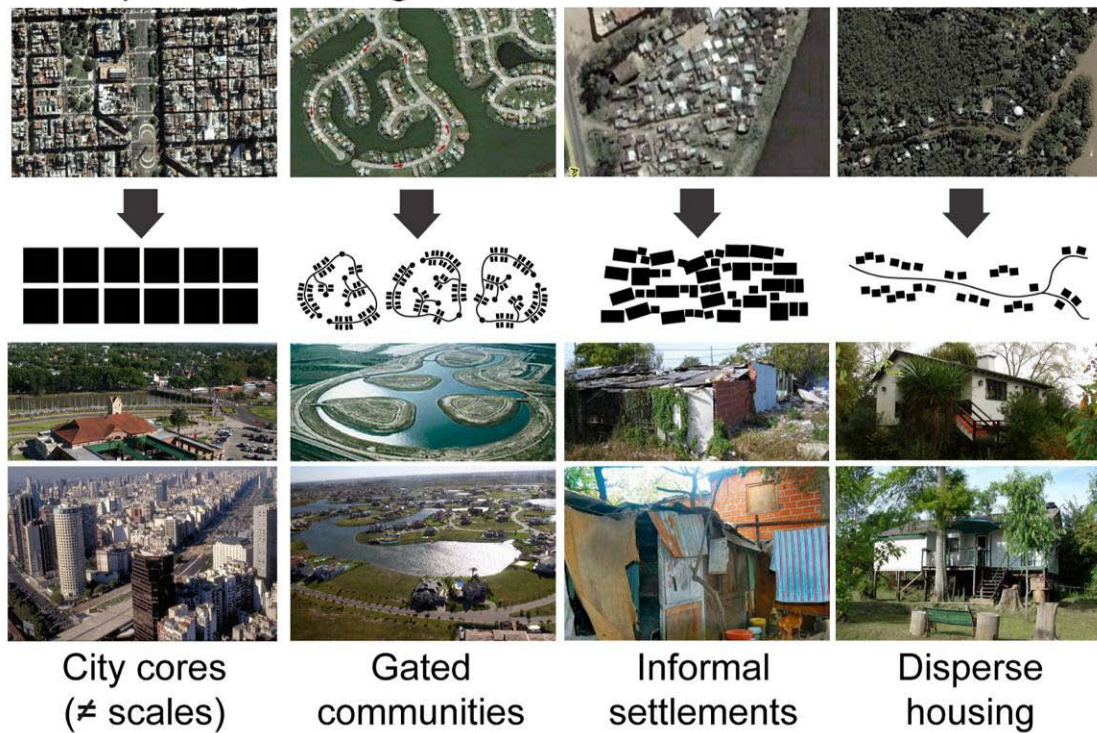


Figure 6: Fires produced by drought and biomass burning practice (2008). Burnt out of 12% of the delta. Image source: NASA.

